Government Policy and Corporate Strategy in Managing Risk and Uncertainty on Technology Deployment and Development in the Regulated Market in the UK
-A Study of Biofuels

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Declaration

I composed this thesis, the work is my own. No part of this thesis has been submitted for any other degree or qualification.

Name……………………………….. Date………………………………………

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Abstract

Technological change when a large social technology is under the processes of deployment and development are complex and uncertain. In this dynamic context, risks and uncertainties (R&U) incurred are unavoidable, which might obstruct the progression of the technology implementation and innovation. Hence, a set of mechanism and strategy are required from the stakeholders to facilitate these two processes and to deal with R&U arise. This research studied biofuels in the UK by looking at the context of a regulated market. The Scottish Government and two oil companies (BP and Shell) were selected as cases studied. Subsequently, an overarching research question was formulated to drive the research "How these major actors interact with one and another to deal with R&U arising from technological change during a technology deployment and development?" By using Social Shaping of Technology (SST), integrating with Risk Governance and the Risk Regulated Regime; an interdisciplinary concept has been developed. The application of SST was to broaden the risk governance and risk regulated regime, helped to look at R&U of technological change from a social dimension. The research was grounded on social constructionism under an exploratory study. A qualitative case study approach was adopted, backed by three data collection methods-interview, observation and document analysis. This research was aimed to investigate the driving forces for the government and oil companies in taking biofuels as the current energy source for transport; their roles and responsibilities in biofuels deployment and development; interactions taken place, R&U faced during two processes, as well as counteracting strategy implemented to deal with these R&U. After that, explanation building and time series analysis were adopted for data analysis. The research points out there were different types of R&U (expected and unexpected) arose when a technology undergoes the processes of technological change. These different types of R&U required different strategies to deal with. Therefore, the regulators have to set a clear direction for a technology deployment and development, as well as to have the control mechanism with precautionary principle instituted, in order to facilitate the technology implementation and innovation. Meanwhile, oil companies are collaborating with the governments, to commit consistent biofuels supply which fulfil the requirements set by the regulators; as well as established various types of partnership with biotechnology institutions/agriculture industry to conduct the next generation biofuels (NBG) R&D. Such seamless interactions and cooperation, not only aim to reduce the possibilities of R&U occurrence, to minimise the impacts, but also to set a path for the ease of technology adoption and innovation. Therefore, apart from satisfying their respective internal interests of political and economic gains; these two actors have to safeguard the social, economic and environmental benefits for the interests of the general public.

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Abbreviations

1G	First generation
2G	Second generation
3G	Third generation
ACO	Automobile Club de l'Ouest
ACORD	Advisory Committee on Research and Development
ALARA	as low as reasonably achievable
ALARP	as low as reasonably practicable
ASU	Arizona State University
BACT	best available control technology
BM	Behaviour Modification
BRM	biofuels regulated market
BSCOs	Biofuels Sustainability Compliance Officers
BSE	Bovine Spongiform Encephalopathy
BSI	Better Sugarcane Initiative
BTL	biomass to liquid
CBC	Canadian Broadcasting Corporation
CCW	Countryside Council for Wales
CEN	European Committee for Standardisation
CLCV	Consultation on Low Carbon Vehicles
CoEBio3	The Centre of Excellence for Biocatalysis, Biotransformations and Biocatalytic Manufacture
CPRE	Council for the Protection of Rural England
CVP	Carbon Vehicle Partnership
DfT	Department for Transport
DOE	Department of Energy
DPB	Directive on the Promotion of Biofuels
EBB	European Biodiesel Board
EBI	Energy Biosciences Institute
eBIO	European Bioethanol Fuel Association
EEA	European Environmental Agency
EIA	Environmental Impact Assessments
ES	economic system

ESR	emerging systemic risk
ETSU	Energy Technology Support Unit
EU	European Union
EUBD	European Union Biofuels Directive
F1	Formula One
FAME	fatty acid methyl ester
FE	fossil energy
FGTI	five general types of institutions
FT	Fischer-Tropsch
G&S	green and sustainable
GHGs	greenhouse gases
HC	Hydrocarbons
HSE	Health and Safety Executive
ICE	internal combustion engine
IG	information gathering
I_i	Institutions
IMCAS	Academy of Sciences
IOCs	international oil companies
IP	Interest Pressures
IRGC	International Risk Governance Council
IUCN	International Union for Conservation of Nature
JDA	Joint Development Agreement
JV	Joint Venture
LNG	liquefied natural gas
LSTS	Large Social Technical System
M&A	mergers and acquisitions
MF	Market Failure
MotoGP	Moto Grant Prix
MRSA	Methicillin-Resistant Staphylococcus Aureus
NAO	National Audit Office
NGB	Next Generation Biofuels
NIMBY	Not In My Back Yard
NOAELs	no-observed-adverse-effect-levels

NPG	Nature Publishing Group
NPV	Net Present Value
NWEEP	North Western Europe Exchange Project
OECD	Organisation for Economic Co-operation and Development
OR	Opinion Responsiveness
P.L.C	Private Limited Company
P&C	Principles and Criteria
PUM	Pearson Uncertainty Map
QIBEBT	Qingdao Institute of Bioenergy and Bioprocess Technology, Chinese Academy of Sciences
Qs	Quadrants
R&D	Research and Development
R&U	risk and uncertainty
RAP	Renewables Action Plan
RC	Risk Communication
RE	Renewable Energy
RED	Renewable Energy Directive
REDD	Reduction of Emissions from Deforestation and Degradation
REfT	renewable energy for transport
RFA	Renewable Fuel Agency
RFD	Renewable Fuel Directive
RG	Risk Governance
RM	Risk Management
RRR	Risk Regulation Regime
RSB	Roundtable for Sustainable Biofuels
RSPO	Roundtable on Sustainable Palm Oil
RTF Certificate	Renewable Transport Fuels Certificate
RTFO	Renewable Transport Obligation
S&T	Science and Technology
SA	strategic alliance
SERA	Socialist Environment and Resources Association
SFAz	Science Foundation Arizona
SG	Scottish Government

SS	Standard Setting
SSP	Sustainable Sourcing Policy
SST	Social Shaping of Technology
SSTR	Social Shaping Technological Risk
TERI	The Energy and Resources Institute
UK	United Kingdom
UKPIA	The UK Petroleum Industry Association
UNCTAD	United Nations Conference on Trade and Development
UNFCCC	United Nations Framework Convention on Climate Change
UoD	University of Dundee
WRA	World Refining Association
WWF	World Wide Fund

Chapter 1 Introduction

Demand for mobility through international/national transport system is critical to the global, regional and national economic growth. Yet the existing transport infrastructure which underpins today's economy is vulnerable, due in part to its overwhelming dependence upon a single fuel source-hydrocarbon. In recent years, the issues of energy security and environmental preservation have made hydrocarbon consumption a primary area of concern for many developed countries. Firstly, the hydrocarbon reserves are concentrated in a relatively small number of countries, many of them beset by economic and political problems that threaten their stability of supply. Hence, these myriad political, social and economic factors are making trade between oil exporters and highly dependent importing nations increasingly tense/vulnerable to disruptions.

Secondly, extracting hydrocarbon from the ground also means taking out the carbon captured in the form of liquid/gas, then releasing them into the atmosphere. According to a report from the European Environmental Agency (2008), regional road transport generates about 1/5 of the EU's CO_2 emissions, with passenger cars responsible for 12%. This makes road transport one of the most prioritised areas targeted for intensive greenhouse gases (GHGs) reduction.

World mobility is growing exponentially. The increasing demand for hydrocarbon is pressuring on global oil reserves. GHGs generated as the consequence of the fuels used have caused global warming and contributed to climate change. This leads to questions such as “How to reduce the GHG emissions, while maintaining the capability to mechanise the economic/transport system?”, “How to make transport energy sustainable?” and “How to strike a balance between limited sources with unlimited demands?” All of these questions are waiting for answers and solutions. Inevitably, both energy security and excessive GHG emissions have alarmed the international community. Sustainability of energy supply represents one of the biggest challenges in the 21^{st} century.

Biofuels appear as one of the alternative for transport energy. Besides biofuels, other potential sources such as electricity and H_2 are favourable as elements for the Renewable Energy for Transport (REfT). However, biofuels gained global attention have become the front runner. Biofuels, either as low blend use in the existing internal combustion engine (ICE) or as neat form used in green cars, would allow partially energy security to be achieved for nations which do not produce oil and gas. Furthermore, biofuels could reduce the GHG/CO_2 emission both through tailpipes and posses natural carbon neutrality. The benefits of biofuels allow the increasing fuel demands to be met, while the GHG emissions could be halved.

However, looking only at the technical convenience of biofuels, does not justify why they gained the favourable front runner position. This technology, in fact, is a social product which is shaped by political, cultural, organisational, economic and other social factors that influenced the conditions for its creation and use. Thus, the Social Shaping of Technology (SST) is used to help understanding, by mapping out the actors, to examine the interactions between these actors, to investigate the content of technology and the processes of technology implementation and innovation (MacKenzie and Wajcman, 1985).

The social network for biofuels adoption and innovation is linked to the stakeholders' political, social, economic, environmental and technological forces. All of these forces are interacting within a setting of a regulated market, which signifies biofuels deployment and development processes are socially constructed. Many renewable energy (RE) concerned countries have taken the lead in biofuels implementation and innovation. For example, through regional (the EU) and national (the UK) policies formulation, biofuels are allowed to claim a larger market share for their adoption in regional/national transport markets. Meanwhile oil companies are responsible for supplying biofuels to fulfil the political mandates, market demands as well as to achieve their economic interests.

Compared with the UK Government, the Scottish Government (SG) demonstrates a more progressive effort in the development of the next generation biofuels (NGB). Working under the Devolved Matters, the SG has undertaken some significant pioneering activities, such as the establishment of the UK's first biodiesel plant, and the first biofuels research centre. Furthermore there are some ongoing R&D projects which foster the NGB development in Scotland. There are obvious different affinities (as evidenced by their respective policies, political visions and directions), where the UK Government is aligned to H_2/electricity, while the SG prefers biofuels. This justifies why the SG is selected as one of the case studies.

BP and Shell are also chosen for study. Both BP and Shell are internationally well-known oil companies, ranked as the 4th and the 2nd world largest corporation respectively among top 500 companies in Fortune Global 500 (2010). As two of the main oil companies operating in the EU/UK, BP and Shell economic motivations are influenced by the EU/UK Government's interests in commencing biofuels blends and further developing the NGB.

During the period of biofuels implementation in the UK, most of the oil companies operating in the UK do not produce their own biofuels, instead buy biofuels from the international market. Up to June 2010, BP and Shell are two of the world six oil companies which are currently pursuing the NGB research (refer appendix 7.1.1). Their progressive efforts in the NGB R&D since 2003 and 2002 respectively, demonstrate their willingness to build upon their pioneering status in the field of the NGB technology.

According to Elliott (2003a), any new technology introduction and innovation for a new marketplace would face a certain degree of risk and uncertainty (R&U) for its development and deployment. Since technology is an inclusive phenomenon, its development and implementation are proceeded by the interaction of various social and technical elements. Technologies, once developed and implemented, not only react back upon their environments, but also generate new implications (Clark and Staunton, 1989; Fleck, 1993). These implications could be both positive and negative. Furthermore, a shift of hydrocarbon fuels' paradigm towards biofuels, signified the technological change, not only includes innovation/diffusion of a new technology, but also has incurred more unexpected R&U after the entrenchment of hydrocarbon technology for more than a century.

When we look at a utility like biofuels, which is used for a nationwide road transport system, the context of such large technology deployment/development is considered as a large social technical system. As advocated by Weber (2002) “large” is the pervasive character of technology, given that it comprises entire countries (like biofuels), while the term “sociotechnical” highlights the fact that new technology cannot be analysed in isolation from its social context. Sociotechnical systems comprise humans, human activities and artefacts (technology) which are characterised by interactions among these components.

Hence, the R&U encountered are far more complicated than those encountered by consumer products when introduced for a particular market segment. If this large technology is mismanaged during its deployment/development, the negative implications generated could be enormous and destructing. Therefore, the regulators and oil companies have to ensure such a large social technology deployment and development must be kept well under control and managed effectively. There are different types of mechanism in place, and various strategies applied to deal with different kinds of expected/unexpected R&U encountered during the first generation (1G) biofuels deployment and the NGB development.

However, two unexpected systemic risks were encountered during the 1G biofuels deployment, resulted in food price increases and destruction of the ecology (refer appendix 7.3.1). To this end, existing theories such as Public Administration and Corporate Risk Strategy could not fully deal with the systemic risks incurred which are unpredictable, highly uncertain, complex and have large scale/prolonged implications. Besides, theories of Technology Management could hardly explain on today's political, social, economic and environmental phenomenon on a continuous, dynamic and evolving technological change happened during the processes of one technology adoption and innovation.

More comprehensive strategies/mechanisms have to be instituted, to ensure biofuels execution and development could lead to successful outcomes and meet the initial objectives set. By using SST, integrated with Risk Governance and the Risk Regulated Regime, an interdisciplinary concept has been developed. This concept is built, to correlate the social shaping of one technology, and social construction of R&U, with strategies to deal with these R&U in a more systematic manner. The application of SST is to broaden the risk governance and risk regulated regime, and to help to look at R&U of technological change from a comprehensive social dimension.

1.1 Research Questions and Research Objectives

My inspiration for this research was based on the comments made by Scurlock (2007). "The British renewable energy policy appears to be focussed too much on electricity production. Many earlier studies have underestimated biofuels potential in shifting the entire landscape of future road transport" (Scurlock, 2007). The shift not only to prosper exporting nations in their agriculture sectors and employment, but also to benefit all the importing nations in their GHG reductions and diversification of energy choices economically.

The focus on biomass (compared with biofuels) is because biomass has been utilised in heat and power generation for centuries, mainly coal/wood as fuels. Meanwhile biofuels are still a developing area which is only recently adopted in many nations, except from the more experienced countries-Brazil and the US. The existing 1G biofuels is derived from food stocks, while the NGB R&D is still ongoing. In fact, biofuels are not an entirely new technology. They are, basically vegetable oil and alcohol, which have been diversified from the food chain to fuel up the automobile. With nearly three decades of the Brazilian bioethanol (sugarcane), and the US five years bioethanol (maze) and biodiesel (soy) implementation, they are not appearing as “new and high-technology” which would capture the world attention. As the NGB would only be commercially available five-to-ten years from 2008; currently there are too few tangible the NGB results which capable to demonstrate the practical application and convince the world of its potential. Therefore, the current intensive NGB R&D projects remain confined to laboratories.

A qualitative case study method is employed to investigate the roles and strategies taken by the SG and the two leading oil companies-BP and Shell, to answer the leading research question: “How these major actors interact with one and another to deal with risk and uncertainty arising from technological change during a technology deployment and development?”

The role of the SG is determined by the Reserved and Devolved Matters (refer appendix 4.2.1) outlined by the UK Government. Therefore the research looked into:

(a) How biofuels became one of the current renewable energy sources for transport?

(b) What are the Scottish Government's roles in biofuels deployment and development?

(c) What mechanisms are in place to create a supportive environment for oil companies in pursuing biofuels deployment and development?

(d) What are the risks and uncertainties that appear during biofuels deployment and development?

(e) What strategies have been applied to counteract the risks and uncertainties arising during biofuels deployment and development?

For the oil companies, BP and Shell are also being investigated. They are primarily profit driven entities who have become interested in biofuels technology/business. They are actively engaged in supplying and researching the NGB. The research investigated:

(a) What are the rationales that moved these oil companies into biofuels business?

(b) What are the oil companies’ role in biofuels deployment and development?

(c) How the oil companies have reacted to the government initiatives for biofuels

deployment and development?
(d) What risks and uncertainties appeared during biofuels deployment and development?
(e) What strategies have been adopted to counteract the risks and uncertainties arising during biofuels deployment and development?

Taking the SG, BP and Shell as qualitative cases study; the research could gain insight from the SST angle. It helps us to understand how political, social, economic, environmental, institutional capability and the regulatory setting have all facilitated large technological change on technology deployment and development. Simultaneously, these two processes might also be constrained by the emergence of R&U. Therefore, the research has investigated the strategies applied (by the government and oil companies) from Risk Governance and Risk Regulated Regime to manage and control these R&U. These strategies are imperative to ensure the existing deployment could be continued, while the NGB would be developed for commercial use. Consequently, this led to five research objectives:

1.To investigate the driving forces for the government and the oil companies in taking biofuels as the current renewable energy source for transport.

2.To determine the respective roles and responsibilities of the government and the oil companies in biofuels deployment and development.

3.To understand the mechanism which delivers biofuels deployment and development, and the interactions that take place between the government and the oil companies.

4.To identify the risks and uncertainties faced by the government and the oil companies during biofuels deployment and development.

5.To examine the strategies adopted by the government and the oil companies to deal with risks and uncertainties arising during biofuels deployment and development.

1.2 Research Contributions

The research aimed to get an insight into a large social technology which is experiencing dynamic technological change as it is being deployed and developed. In addition, the focus on corporate/public risk management which dealt with R&U associated with a large technology deployment/development could be utilised for other application, either for private company or government, who is/are interested in advancing biofuels as the REfT. The research portrays the driving forces, the mechanisms, the roles and responsibilities and the interactions of policy maker and the oil companies during biofuels implementation and innovation. Besides, the expected R&U are identified from technology deployment and development processes, and the counteracting strategies are implemented to deal with these R&U as they arise.

These first-hand experiences provide some valuable information which are helpful in decision-making. Firstly, the driving forces and the roles and responsibilities of the political authorities and the oil companies could be accurately defined under the regulated market. This would ensure the effective development of mechanisms/strategies, to help foster collaboration and commitment, leading ultimately to seamless interactions between these two actors to have one technology deployed and developed.

Secondly, R&U identified from the deployment and development processes, and the systemic risks could be a threshold for learning and for keeping the decision makers from falling into the same trap. The counteracting strategies applied to deal with these R&U provide many practical solutions that could be used by others when any stakeholders encounter a similar situation.

To date, the biofuels regulated market is still under-researched. Some of the mechanisms in place are extended from the existing hydrocarbon regulated market. Although they could provide guidance for biofuels operations, they are inadequate for biofuels deployment and development, as the biofuels technology is really different from hydrocarbon. The research generally mapped out the context/content of the biofuels regulated market, described the mechanisms in place and described the interactions between the regulator and the oil companies. The five general types of institution advocated by Gregory and Stuart (2004) are helpful in explaining the general context/content of biofuels regulated market (refer appendix 2.1.3).

1.3 Structure of the Thesis

Chapter 2 reviews some key areas of academic literature pertinent to the topic of the research namely: the regulated market (section 2.1), SST on the large social technical system (section 2.2); R&U arising from a technology development and deployment for both government (section 2.3) and corporate institutions (section 2.4). In addition, an understanding of systemic risk is introduced (section 2.5) with regulator and corporate counteracting strategies on risk governance (section 2.6) and of the risk regulated regime (section 2.7) adopted to deal with these expected R&U and systemic risk.

Chapter 3 describes the method used to meet the research objectives, and draws upon social constructivism philosophy to arrive at a qualitative case study for an empirical exploratory investigation. Chapter 4 begins the case study investigation by examining the SG. By looking into its roles in biofuels deployment and development under the Reserved Matters, the researcher looked at the SG's reactions in responding to the various levels of regulatory authority (EU/UK) for biofuels deployment. In addition, under the Devolved Matters, the SG interaction with different institutions (academic/private sector) for the NGB development is investigated. This chapter also examines how the combination of the EU/UK Government applied strategies to deal with the complexities of the systemic risk occurred during the 1G biofuels deployment.

Chapter 5 and 6 details BP and Shell case studies, which shared much on a common ground. Studying BP's and Shell's economic motivations in biofuels, these two companies are actively engaged in the 1G biofuels supply, while simultaneously pursuing the NGB development. The research examined the rationales, roles and responsibilities and incentives which led BP and Shell to move into biofuels deployment and development. The anticipated R&U defined in literature chapter 2, facilitates corporate R&U identification when companies are dealing with technology deployment and development. These chapters also examine how both companies applied their strategies in dealing with systemic risks occurring during the 1G biofuels deployment.

Chapter 7 then integrates these case studies and presents an analysis of data arising from the research. The concentration on discussion and analysis are driven by the research questions and research objectives formulated, to make sure they have been answered and achieved. Finally, chapter 8 draws together the conclusions for the theory, the research findings and then makes recommendations for a future study.

Chapter 2 Literature Review

2.1 Understand the Mechanisms of Regulated Market under the Mixed Economy System

Preface

There are vast amount of literature about free market under capitalist economy. Yet, there are just a handful of articles discussing regulated market under mixed economy. Through this literature analysis, the researcher aimed to investigate: How the regulated market works? What mechanisms are in place under this type of market setting? To arrive such understanding, we will look into two issues: the regulated market under the mixed economy, and the energy economics leading to renewable energy (RE) adoption.

2.1.1 Introduction

The regulated market is a marketplace, where there is a degree of supervision by government concerning either permissible price movements/market behaviours for the utility assets (Moles and Terry, 1997). According to Gregory and Stuart (2004), since the definitions and classifications of economic systems have become complex; we no longer divide the world into capitalist and socialist/planned economy. Beyond the conventional inputs (land, labour, capital), economic outcomes are also influenced by political, social, geographic and technology.

Biofuels regulated market (BRM) is slightly different from an oil market (at the upstream), yet its criteria are also partly continue (at the downstream) from the conventional oil regulated market (refer appendix 2.1.1). Within the regulated market, the business entities are organised to pursue their private economic objectives. Simultaneously, the business processes are influenced by the interventions of governments in conducting public's socioeconomic responsibilities while to fulfil the regulators' own political motivations. Despite the regulated market is complicated, there is still a grounded theory advocated by Gregory and Stuart (2004)-the five general types of institutions (FGTI), helps to understand the general concepts of the regulated market.

2.1.2 Institutional Classification

Gregory and Stuart (2004) explain, traditionally, economic systems were classified according to the “isms”-feudalism/capitalism/socialism/communism. These classifications identified systems in two characteristics: the “ownership” and the means of “production” both are based on the institutional features. However, institutions exist in a large number of forms: corporations/unions/economic customs. Since they are varying in complexity, there is no universally accepted definition of “institution”.

North (1990) defines “institutions are the rules of the game of a society under which economic decisions are made. Fundamentally, institutions are the humanly devised constraints that shape human interactions. Consequently, they structure incentives in human exchange whether political, social or economic.” This defines institutions are broadly interpreted to include legislation, organisations (governments) and corporations, or any other political, social, and economic rules that affect the way people deal with each other in the exchange of private/public goods/services. Whenever there are rules of behaviour, there must be a means of enforcing these rules. Thus, institutions consist not only the rules themselves; but also the means of their enforcement. Voigt and Engerer (2002) cite five types of rules and enforcement mechanisms in Table 2.1.1 (refer appendix 2.1.2)

Table 2.1.1: Types of Rules and the Means of Enforcement

Rules	Enforcement
Convention	Self enforcing
Ethical	Self commitment
Customs	Informal social control
Private	Organised private enforcement
State Law	Organised state enforcement

Source: Voigt and Engerer 2002. pp. 132. Ch. 2

2.1.3 Mechanisms of Regulated Market under Mixed Economy

Gregory and Stuart (2004) explain, an economic system (mixed economy) has a set of institutions for decision-making, implementation, concerning production, income and consumption within a geographic area. Therefore, the economic system consists of mechanisms, organisational arrangements and decision-making rules (laws, traditions, beliefs, attitudes, values and behaviour stated in Table 2.1.1). They could directly/indirectly affect economic behaviour and outcomes. Since the economic systems are multidimensional, a feature can be formalised as:

$$\mathbf{ES}^{1} = f\,(I_1, I_2, \ldots. I_n)$$

An economic system cannot be defined with a single institution (property ownership); rather the full set of institutions must be known before ES is specified. The FGTI is used to differentiate economic systems from one another (refer appendix 2.1.3), and they are:

(a) Organisation of decision-making: the structure

(b) Mechanisms for the provision of information and coordination: market and plan

(c) Property rights

(d) Mechanisms for setting goals and inducing people to act: incentives

(e) Procedures for making public choices: the role of government

2.1.3.1 The Organisation of Decision-Making

Simon (1966) explains "organisation refers to the complex pattern of communications/relations in a group of human beings." According to Montias (1976), "an organisation consists of a set of participants regularly interacting in the process of carrying on one/more activities". There are two perspectives: rules and relationship, which guide the decision-making processes.

(i) Rules as Guidelines

In an organisation, goals exist and information is created. According to Ben-Ner et al. (1993), individuals participate in an organised behaviour, pursuing self-interest constrained by bounded rationality, and responsibilities towards an organisation.

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1 This equation indicates, an economic system (ES) is defined by its institutions (I_i), where there are n such attributes.

Economic theory assumes we make perfectly rational decisions armed with perfect information. However, if we lack of perfect information and outcomes are uncertain, we cannot rationally weigh every decision to find the maximising outcome. In such situation, we turn to the use of rules as guidelines.

(ii) Relationship of Principal-Agent

Gregory and Stuart (2004) explain, an organisation is characterised by the levels at which resource allocation and decisions are made then executed. In a decentralised organisation, decisions are made primarily at low levels of the organisation. In a centralised organisation, most decisions are made at the highest levels. Decision-making level reflects the organisation's structure, the manner which the organisation generates/utilises information and allocates authority/responsibility.

In most organisations, a superior-subordinate (principal-agent) relationship implies that a principal is a party who has controlling authority that engages an agent to act, subject to the principal's control/instruction. An agent is a party that acts for/on behalf, or as a representative of a principal. Once the relationship is established, the principal is responsible to monitor performance, ensuring the agent is providing the services as specified/required (Gregory and Stuart, 2004).

2.1.3.2 Mechanisms for Information Provision and Coordination

In a centralised organisation, the authority that makes decisions rests in a single central command that issues orders to lower units. The decentralised, would be a structure where all decision-making authority rests with the lowest subunits independently. In reality, perfect centralisation of information is impossible, because of the mass of information on prices, locations, time and quality. Organisations must have some degree of information decentralisation. Typically, lower level units have an information advantage concerning their local circumstances and accessibility compared with higher level units (Gregory and Stuart, 2004).

(i) Market and Plan

Gregory and Stuart (2004) explicate, market and plan are two mechanisms for providing information/coordinating decisions in organisations. However, there is no simple relationship between the level of decision-making and the use of market/plan as a coordinating mechanism. In regulated market, it has to combine a considerable concentration of decision-making authority and information, in large corporations with substantial state involvement. Coase (1937) posed the question of why some activities are carried out through markets, whereas others are carried out by directives/plan from government. Coase then concluded: activities will be carried out by plan whenever the transaction costs[2] of using markets are too high.

2.1.3.3 Property Rights

Montias (1976) states, institutions also differ in how property is owned. Ownership is an amalgam of rights that individuals may have over objects/claims on objects/services. There are three forms of property ownership: private, public and collective/cooperative. Differences in ownership rights affect economic outcomes. As the owners seek to maximise their incomes, capital will be disbursed to yield the highest rate-of-return commensurate with the risk involved. If capital is owned by the state, the rules of capital allocation are different, because greater attention may be paid to long-term social rates of return (Gregory and Stuart, 2004).

2.1.3.4 Incentives

Pryor (1974) explains, an organisation can be characterised in terms of the incentives that motivate people. “Goals and incentives are vital links in understanding the transformation inputs into effective actions.” Montias (1976) adds, an incentivise mechanism should induce agents to fulfil the directives of the principals. The

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2 It is the cost incurred in undertaking an economic exchange; which considers the relative merits of conducting transactions within firms and between firms using markets. It takes into an account of bounded rationality, information problems, the costs of negotiating contracts (Black, et al., 2009a), the costs in making a bargain over and above the benefit exchanged, costs of travel, time to complete an exchange, the research costs, bargaining costs, enforcement costs (Law, 2009); opportunity cost, agency costs if an agent is used and for opportunism (Law and Smullen, 2008). Transaction costs can reduce the volume of transactions, as they reduce welfare by suppressing mutually beneficial transactions and using up resources. Through incentives provision to individuals to economise and bundle their transactions is a way to overcome it (Calhoun, 2002a), while businesses and markets prefer to see lower transaction costs over time as this will improve profitability (Law and Owe, 1999).

principal can devise material[3]/moral[4] incentives to motivate the agent.

2.1.3.5 The Role of Government

The government must provide public goods[5]. Even in market economies, public goods must be provided because non-payers/free riders, cannot be prevented from using them (Gregory and Stuart, 2004).

2.1.4 Leading to the Understanding of Mixed Economy

The researcher sought advices from two scholars of economics from the Edinburgh University, in affirming the type of economy under the biofuels market in the UK. "There is less interest in classifying national economies than there used to be after the fall of Soviet type economies twenty years ago. In some respects the UK still has a mixed economy, based on an ownership model of industry being part publicly and part privately owned, although not so much as in the 1948-88 period when Britain had large nationalised industries," said Rutherford (2009). "The UK is a mixed economy, as are other OECD economies. It involves a mix of private and public ownership and allocation by markets/government, as does the biofuels sector. Describing it as mixed is not particularly interesting. What is more interesting is the precise nature of the mix" Sayer (2009).

Mixed economy is defined as an economic system which combines elements/characteristics of the market economy with elements of a planned economy. The state generally plays a larger role in setting policy, rules and objectives (Scott and Marshall, 2009). Institutionally, a mixed economy is a mixture of state and private enterprises, where the economic activities are carried on by individuals/firms with some degree of centralised states decision taking (Black, et al., 2009b). Besides, Rutherford (2007) comments, the mixed economies attempted to soften the effects of

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3 Material incentives promote desirable behaviour by giving the recipient a greater claim over material goods (Gregory and Stuart, 2004).
4 Moral incentives reward desirable behaviour by appealing to the recipient's responsibility to society and raising the recipient's social stature within the community (Gregory and Stuart, 2004).
5 Roads must be built, water and electricity to be supplied, children must be educated, and healthcare provision must be made.

capitalism, without adopting the strong central controls of many types of socialism (refer appendix 2.1.4).

2.1.4.1 Balancing Between Government and Private Sectors

Stiglitz (2000) states, free markets often fail, and governments must play a role in correcting the failures of the market. There is an agreement that there are many problems which the market does not address adequately. However, the recognition of the limitations of government implies that, government should direct its energies only at areas in which market failures are most significant; and where the government intervention can make a significant difference. The dominant view is that limited government intervention could alleviate the worst problems. Thus, the government should take an active role in balancing the economic system and alleviating the worst aspects of poverty, while private enterprise should play the central role in the economy. This attempts to find ways for government and markets in working together and strengthening each other.

Therefore, industry like telecommunications, rails, airlines have loosened from being regulated, while the energy market is still operated under control. Since the oil companies have been largely privatised accordingly, their businesses are organised- not only focusing at profit seeking; but their business operation also is strongly influenced by the intervention of governments to conduct public socioeconomic activity.

2.1.5 Energy Economics and Renewable Energy Adoption

According to Eden, et al. (1983), energy economics are concerned with the availability of energy resources and their relation to economic activity. The industrialised world is in an uncertain stage of transition from low-cost hydrocarbon fuels to higher-cost, which the prices fluctuating accordingly.

The developing world will provide an increasingly important fraction of the world energy demand. Surged by the economic growth, it will have an increasing demand for world energy resources. The econmic growth in both the industrialised and the developing world will be disturbed/frustrated by energy shortages. The world energy demand is now two/three times its level when coal was the dominant fuel which associated with changing life styles and rising standards of living.

Both energy and economic policies are determined on a national basis. Investment/trade in energy supplies forms a key component of economic activity, that no satisfactory energy/economic policy can ignore the potential political/social consequences of the scarcity of energy. The time scales need to be considered in formulating energy policies, are an order of magnitude longer than those commonly considered for economic policies. Yet, no one can foresee the future energy situation for decades. This recognition of uncertainty should play a major role in energy planning. Policies and strategies need to be designed to remain robust under a variety of alternative futures. The assessment of alternative energy strategies for costs and risk avoidance is an essential part of planning (Eden, et al., 1983).

According to Stevens (2007), in the oil regulated market (which biofuels blends are currently supplied by oil companies), the key to oil companies operation lie in the role of the institutional power-which are in oligopolistic market structure. While the supply-and-demand influences the price determination, the context of market is highly controlled by government intervention.

Oligopolistic is a market with a small number of sellers/producers, and oil/biofuels markets have limited competition (Catherine and Stevenson, 2005; Calhoun, 2002b). Most of the oil companies operating in the UK are international oil companies (IOCs). Since 1998, the IOCs have experienced mergers and acquisitions, which significantly increased the concentration ratios in the upstream and downstream of the industry (Luciani and Salustri, 1998). This was triggered by the oil price collapse of 1998 which made the purchase of others' reserves an attractive proposition. Certainly mergers and acquisitions were perceived as synergies to reduce costs, it also gave an opportunity to reshuffle the new asset portfolio to sell the lesser performing assets. Once the first mega-merger in the oil history had taken place between BP and Amoco, shareholders' expectations created a feeding frenzy forcing the others to follow and the industry became more concentrated (Stevens, 2007).

In the last 20 years, oil importing countries have pursued three broad strands of policy: deregulation, imposition of sales taxes and measures to address security of supply concerns (Fried and Trezise, 1993; Mitchell, 1994; Bohi and Toman, 1996; Mitchell et al., 1996; Andrews Speed et al., 2002; Leiby et al., 2002). The trends of recent years have been for the legal and regulatory, to encourage greater private sector involvement in the industry and to deregulate the sector. In the downstream and midstream, the emphasis has been on maintaining competition. For example, during the mega mergers, the competition authorities notably in the EU have examined the implications and in most cases forced some degree of divestiture to maintain competition. The emphasis has been on moving what was a largely state controlled sector into the private sector and now these oil companies have been transformed to public limited companies. This has involved a combination of privatisation and deregulation. In the upstream, the main change has been opening acreage for exploration and development for IOCs, driven by a desire to access capital and technology (MacKerron and Pearson, 1996; 2000).

Even though these oil companies are privatised organisations, the government is also playing its part to intervene the oil market for the sake of public socioeconomic responsibilities: taking care society's welfare and protecting those in energy poverty. Additionally, the government is also eyeing on the lucrative taxes which oil companies could generate. Supported by Paga and Birol (1994); Bhattacharyya (1995) and Stevens (2007): most of the governments in OECD have been imposing ever higher sales taxes on oil products. Most recently, some governments from developing countries have moved away from protecting consumers from the oil shocks of the 2008 through subsidy, to raising final prices through sales taxes. The motive has been the attraction of raising revenue from oil products disguised under rhetoric to protect the environment/society, although rising international prices have made the cost of continuing subsidy increasingly difficult to bear. The reality is oil products have a large tax base and an inelastic demand allowing for high tax rates-which are a very attractive source of net revenue to any exchequer.

Several broad policy areas are under considerations: reduce oil demand, develop alternative technologies (like biofuels), increase domestic supplies, diversify sources of oil imports and build up strategic stocks. While such policies can be driven by security of supply concerns, they carry implications for other energy policy objectives, such as environmental concerns (Stevens, 2007).

In the transport sector, the personal mobility powered by automobiles has become an entrenched characteristic of society in developed/developing countries, which reinforces the view that world energy demand for transport will continue to rise. The average yearly finding rate for world oil reserves has been lesser than total consumption for some years. If this continues, it is inevitable the oil production will eventually decline.

The first policy option to solve security problems is to reduce the demand for oil. However Stevens (2007) agrees, this is more complex than it might seem. Since the oil price shocks of the 1970s, the only realistic option is to try to reduce oil intensity lies, in reducing its use in the transportation sector. Consequently, there is undoubtedly considerable scope for further improvements in automotive fuel efficiency.

The second option is to encourage alternative technologies for transport which used different fuels. Since the millennium, the environmental issues play a crucial role in oil markets, and will remain a central dimension of policy because of the environmental concerns dominate all stages of the industry. In the production of crude oil, there are issues of access to wilderness areas, plus the negative impact of operations ranging from gas flaring to the disposal of drilling muds. Environmental policy outcomes in the upstream, all of which will increase production costs and reduce supply, will depend upon the extent to which other policy drivers, most obviously supply security, supersede environmental concerns. At the same time, concerns regarding emissions as a result of burning oil products are creating serious pressures for tighter environmental policy. The most general and widespread regulations are concerning sulphur content in diesel and the issues related to the emission of greenhouse gases (GHGs). Based on CO_2 emissions, in a world of a true carbon tax, arguably oil has caused the GHG emissions leading to the climate change (Stevens, 2007).

These few years, calls for RE have awaken awareness and demands. Such substitution involves the cost of diversion of other resources (solar, wind, tidal/wave, hydro, geothermal, biomass), manpower and skills, and also requires time to achieve. The lead time for a transition to new RE is varying widely with higher cost. However, the extent of cost itself could not be de-facto for oil sustainability. The fact is, hydrocarbon is a depleting resource. Historically, cheap natural gas and low priced oil in the past have penetrated the fuel market and displaced coal. With the resurrection of RE-if properly developed with the economies of scale would create another evolution to complement hydrocarbon.

2.1.6 Conclusion

The researcher utilised the FGTI advocated by Gregory and Stuart (2004) to analyse the UK BRM (refer appendix 2.1.3). Besides, important concepts advocated by Eden, et al. (1983), Stevens (2007) on energy economics led to the identification of three factors (energy security, overpopulation and environmental concern) which called for the RE adoptions (as biofuels for transportation). Inevitably, there are limitations for this literature analysis. Since the oil regulated market and mix economy disciplines are too broad; this literature analysis is aimed to provide a general understanding of the mechanisms and operations under the BRM, which have the similarities with oil market.

2.2 Social Shaping Technology: Large Social Technology Deployment and Development

Preface

The processes of biofuels deployment and development are complex. These processes are continuous over time involve the nationwide-supply of biofuels (as utility[6]) by oil companies under the supervision of the government; while the next generation biofuels (NGB) R&D are simultaneously underway.

There are vast literature of Social Shaping Technology (SST) contribute to the analysis of technology. Selected publications of MacKenzie and Wajcman (1985), Williams and Edge (1996), Rip and Schot (2002), Weber (2002) are substantial in helping towards a better comprehension of a large social technology deployment and development. The SST's theory attributes, technology, is a social product which shaped by political, cultural, organisational, economic and other social factors. Thus, the SST perspective helps the understanding by mapping out the actors, examine the interactions between these actors, and contextualise the activities (decisions in identifying, selecting, developing, adopting and innovate a technology) during one technology deployment and innovation.

2.2.1 Introduction

SST advocated by MacKenzie and Wajcman (1985) examines the content of technology and the processes of implementation and innovation. It explores a range of social factors which pattern the design and implementation of technology. Therefore, SST concludes, technology does not develop according to an inner technical logic, but is instead is a social product, patterned by the conditions of its creation and use. Every stage in the generation and implementation of new technologies involves a set of choices between different technical options.

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6 Utility is the basic infrastructure for public services: electricity, water, gas, fuels and ICT (Black, J. et al., 2009; Black and Myles 2009). Biofuels are one of the utility since they are used at large social context, blend with hydrocarbon in powering the entire national road transport system.

Weber (2002) introduces the term "large social technical system" (LSTS). "Large" is the pervasive in character of technology, that it comprises entire country (like power supply) or connecting the world (ICT). Meanwhile "sociotechnical" is to highlight new technology cannot be analysed isolated from its social context. The sociotechnical systems comprising humans, human activities and artefacts which characterised by interactions among these components (Trist, 1981). Hence, government as one of the actors within the system can shape new technology in a sustainable way, and to ease problems/risk and uncertainty (R&U) the technology may cause.

2.2.2 The Concept of Large Social Technical System

Weber's LSTS framework consists of five distinctive features:

(a) technology

(b) actors

(c) interactions among/between actors

(d) System structures

(e) the exogenous system environment.

The framework (Figure 2.2.1) represents an attempt to integrate SST theories into a framework for a constructive research. It is to emphasise three realms: politic, economic and technology which society has considered. According to Weber (2002), the framework is an explicit method of delimiting and studying a selected segment of sociotechnical, to keep its description manageable. In practice, it could be difficult to justify the delimitation of such specification. If later empirical analysis reveals that the system has a significant influence on environment, the definition of the system boundaries should be reconsidered.

The framework delimitations need to be justified individually for each empirical study. In some cases, it may be appropriate to define at specific level (global, national, regional or local/sectoral). Due to changing patterns of interaction, a framework's boundary could be changed over time. Keeping these considerations in mind, the framework should be interpreted as a guide to structure the description of a particular study. As depicted in Figure 2.2.1, the framework covers both the micro perspective (actors and interactions), and the macro perspective of structural transformations. It puts technology in the centre of a network of social relationships, to reflect the interdependence between technology and the social forces while the entire framework is embedded in its environment setting (Weber, 2002).

2.2.3 Five Distinctive Features

There are five features advocated by Weber (2002) under the LSTS:

1. The technology: which is subject to change and innovate/compete with the emergence of new niche solutions.
2. Actors and their motivations/interests: users and suppliers of technology with political authorities, intermediary organisations and interest groups.
3. Interactions among actors: determine the selection of technology, with the generation of strategies-mainly for decision-making on technology adoption/innovation.
4. Structures: provides the evolving settings and institutions which interactions take place (as discussed in appendix 2.3).
5. The exogenous environment: the system which adapts to the changes taking place from the environment.

2.2.3.1 Technology

Generally, a technology represents more than the technical hardware/functions. It comprises the entire body of knowledge (codified and tacit) and organisational practices to make it operate.

Since technology is an inclusive phenomenon, its development is continued by the interaction of various social and technical elements. There is no linear effect of technologies upon society, so too the conditioning of technologies by social factors is not a one-way process. Technologies, once developed and implemented, not only react back upon their environments, but also generate new implications (Clark and

Staunton, 1989; Fleck, 1993). Consequently, to characterise a technology and its emergence, the multi-dimensional and multi-actor framework are needed. Thus, whereas a technology may be on one hand subjected to the limitations of what is physically feasible, the remaining set of options is further constrained by the social context (Weber, 2002).

2.2.3.2 Actors

SST states: technologies are not neutral, but are fostered by groups to preserve/alter social relations (Hard 1993); they are “politics pursued by other means” (Latour 1988). Thus, SST is influenced by a desire to democratise technological decision-making, to forms the social accountability and control. New technologies embedded in society, and their impacts depend on the processes of contextualisation. In the co-evolution of technology and society, a variety of actors are interested in influencing technological change with their own goals (market success, sustainability and others). Through actions and interactions of these actors, technologies evolve and adopted (Rip and Schot, 2002).

In describing the negotiability of technology development, there are choices inherent in both the design of individual artefacts and systems, and in the direction/trajectory/processes of innovation. If technology does not emerge from the unfolding of a predetermined logic or a single determinant, then innovation is a garden of forking paths. Different routes are available, leading to different technological outcomes (Williams and Edge, 1996).

Significantly, these choices could have different implications for society. The characters of technologies and their social implications have opened up for enquiry. The social scientists can analyse the social influences over the particular technological routes taken and their consequences. These are united by an insistence that the “black-box” of technology must be opened, to allow the socioeconomic patterns embedded in both the content of technologies and the processes of innovation[7] to be socially exposed and analysed (MacKenzie and Wajcman 1985).

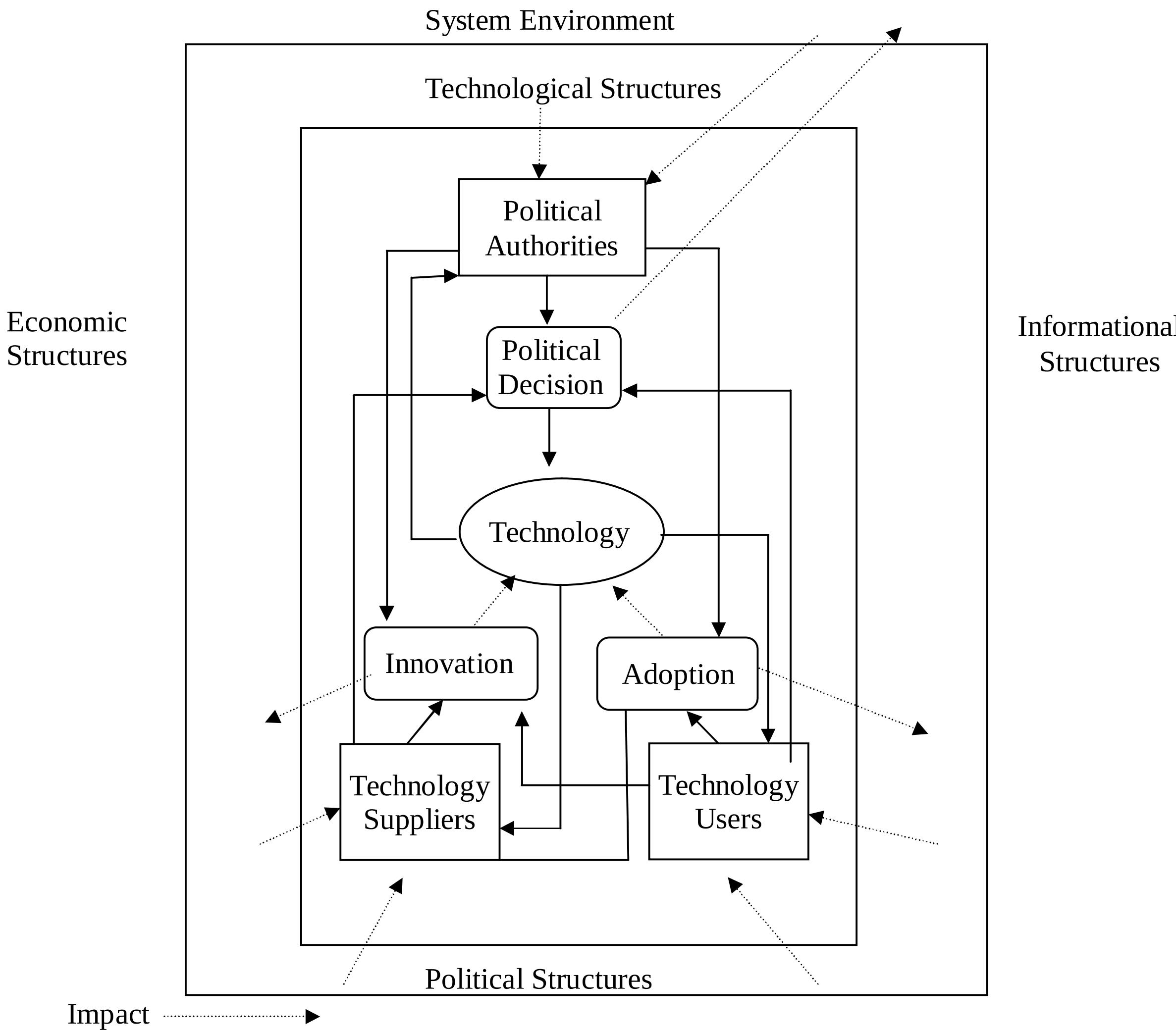

Figure 2.2.1: The Basic Elements of the Framework
Source: Weber, K. M., 2002. pp.331.

This opens up two issues. Firstly, the negotiability of technology (Cronberg, 1992)- which highlights the scope for particular groups and forces to shape technologies to their ends; and the possibility of different kinds of technological and social outcome. The technological development and implementation involves processes of collaboration between suppliers and users, a hybrid between the ideal-type market

7 According to Dosi (1988) and Kemp et al. (1991), innovation decisions predominantly depend on:
(i) the further opportunities offered by a new technology,
(ii) the perceived opportunities to appropriate the benefits of innovation, and
(iii) the expected patterns of demand.

relationship and a social inter-organisational interaction (Brady et al., 1992; Lundwall, 1993).

Secondly, it raises issue about irreversibility (Collingridge, 1992; Callon, 1993)-the extent/manner in which choices may be foreclosed as earlier technological choices will pattern subsequent development (Rosenberg, 1994). Certain options may be selected and become entrenched, as a result of the tendency of new technologies to develop cumulatively, erected upon the knowledge-base, social and technical infrastructure of existing technologies, particularly where increasing returns to scale of investment result in "lock-in" to established solutions (David, 1975; Arthur, 1989; Cowan, 1992).

Negotiation processes precede the final decisions regarding a new technology, but apart from these negotiations, it needs to be explained by which general motivations and processes an actor (an individual, a private company or a public body) takes a decision. In making decision under limited information (about developments available and emerging technical options), actors (users, suppliers, political authorities) are confronted with the necessity and possibility to spend limited resources on different types of activities while remain interacting and negotiating with one another. This serves the purpose of reducing any uncertainty, presumably the best possible decision to be made. During the negotiation process, different types of mechanism are used by the actors involved to affect the final decision, so that they match their own perceived interests well. These interests can be seen as a combination of internal and external interests[8] (Weber, 2002).

2.2.3.3 Interaction and Decision-Making Processes

According to Weber (2002), the decision to adopt a technology is the result of interactions with others. A decision is the final result of a negotiation process in conjunction with the interests/goals/expectations of the decision-taking actors. These

8 Internal interests: reflecting the self-referential aspects of decision-making. External interests: Decision-making in the sense of social/economic success for the public benefits (Weber, 2002).

negotiation and decision-making processes take place within the limits of certain rules and institutional settings[9]. New control measures are analysed, involving not only government bodies but also representatives from industry/other relevant social groups.

The innovation and adoption of new technologies, and the control are determined by overlapping groups of actors involved, but in different areas of interaction, each with its specific mechanisms of selection and variation. The organisational settings in which these mechanisms are used can be described with markets, hierarchies or networks. Administrative hierarchies are responsible for the implementation of political decision, but consultation processes in the networks of interest groups also play an important role in the preparation of political decisions. Technological innovations often take place in network type settings (Callon, 1992; Lundvall, 1988) involving suppliers, users of technology, research centres, interest groups and political institutions. These inter-institutional networks pervade the system are responsible for shaping a conducive/(maybe detrimental) climate for a new technology.

2.2.3.4 System Structures

Weber (2002) emphasises, technology develops within a socioeconomic and technological environment can be structured along some categories. These structures are not fixed, but in a continuous process of change-mostly slow and incremental, but on occasions also fast and revolutionary. Being the result of a historical process, these structures could be regarded as the accumulated result of decisions made by the actors in the course of time. They play an important role in framing/constraining individual decisions, but in turn, they are also shaped by individual decisions.

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9 Three types of decisions related to interaction are distinguished as shaping the innovation and diffusion of new technologies (Weber, 2002).
(i) Innovation decisions: the decision of a supplier to develop (and market) a new technology.
(ii) Adoption decisions: made by technology users, after explored alternative options, and the different requirements to be fulfilled.
(iii) Political decisions: taken by political authorities (government), to introduce a new specific regulations.

2.2.3.5 System Dynamics

Weber (2002) explains, an impetus driving change in the framework consists of external pressures such as: societal problems, resource scarcity, major political changes or scientific discoveries from outside the technological realm under study. Within the framework, the main driving forces of change and variation are on one hand rooted in the auto dynamics of technology, opening up new opportunities for future development paths. On the other hand, different types of needs: political, technical, economic and social can induce efforts to generate variety and innovation. Such needs can be driven by exogenous developments, but also can be rooted in the interests/problems/objectives of the actors within the system. Besides, uncertainty adds to the variation in the search for new solutions because ex ante different paths can be worth exploring.

This interpretation implies a notion of a co-evolution, rather than discontinuous. In LSTS, it is not easy to introduce fundamental changes due to structural resistances. However, past histories of such systems show that, once the right matches are established, a fast process of change with pervasive impacts can happen. The underlying reasons for initiating such transformations can be exogenous to the system, as well as coming from within the system. Changing the dominant paradigm of structural settings, mental frameworks of the actors and related sets of interests, can be regarded as a process that requires a high activation impulse (Weber, 2002).

2.2.4 The Dynamism of Technological Development

The innovation journey starts with the identification of a technological opportunity: a new option/pressure to find a solution for a problem. Such options may derive from R&D findings/scientific advance in general. With the tentative introduction of the new product/process in a societal experiment, the complexity increases (Rip and Schot, 2002).

Innovation is seen as a contradictory and uncertain process. It is not just a rational-technical problem-solving process; it also involves social, economic and political processes in building alliances of interests (suppliers, technologists, users, funders, regulators) with the necessary resources and technical expertise around certain concepts/visions, yet unrealised technologies. In this approach, technological development is a spiralling rather than a linear process. The crucial innovations take place both at the design and the implementation stages (Williams and Edge, 1996).

A challenge, not just for technology developers, users, but increasingly also for policy makers and critical societal groups, is to influence technological change at an early stage, when irreversibilities have not yet set in while one can sway the balance between desirable and undesirable impacts. The problems face during technology R&D is not just cognitive (how to anticipate the unpredictables), but also a sociopolitical (Rip and Schot, 2002).

The suppliers orient themselves to the new technology where economies of scale and scope are exploited; and recognition by users, of further possibilities which create new sociotechnical linkages. The sector starts to change, and its relations with other sectors are also changing. The latter can become so important that the technology driving such changes by being taken-up widely-called as a pervasive technology, and will construct a new technoeconomic paradigm (Freeman 1992).

The argument about actors and analysts is mirrored in practice by the contrast between insiders (who will take a concentric view) and outsiders. These considerations set the scene which addresses the problem of keeping the overall picture in mind, in spite of a concentric bias. The simplification is to keep the overall picture manageable, to reduce four poles to characterise activities: science, technology, market/society and regulation; each of them operationalised with dominant intermediaries and interactions (Rip and Schot, 2002).

If actors want to exert influence and change an emerging path in another direction, they face the momentum that has been built-up and following the increasing alignment. Internal actors are constrained by their inclusion in the dynamics, while external actors have to overcome the distance between inside and outside (Garud and Ahlstrom 1997). In practice, the first requirement is to understand the dynamics of such developments in context. It is important to enrich the innovation journey, by anticipations and response. Anticipations of outcomes (including impacts of the technology on society) must be an ongoing concern, rather than ad-hoc efforts to persuade a regulator that the journey could be continued. The learning made possible through scenarios-especially important at an early stage (Rip and Schot, 2002).

As with emerging rules and institutions, a precarious product of actions and interactions of actors, requiring care and repair all the time, turns into a stable regime which orients actions and perceptions. This is the way to understand how design hierarchies become established (Clark 1985), and the regime concept can be used to broaden the notion of design hierarchy (Van de Poel 1998). Cumulative effects may thus lead to the emergence of new regimes, or shifts in existing regimes. This is a multi-actor, multilevel process, in which no single actor can sway the balance intentionally (Rip and Schot, 2002).

2.2.5 Conclusion

Weber's (2002) five distinctive features highlighted [1]technology, [2]actors, [3]interactions, [4]system structures and [5]exogenous system environment, could be extended for the analysis of deployment and development of biofuels. The concept advocated by Rip and Schot (2002), is helpful to widen the understanding on uncertainty caused by institutional change, emergence of new actors to imprint new characteristics for technological innovation.

2.3 Identifying Risk and Uncertainty from Renewable Energy Projects in the UK

Preface

Renewable energy (RE) is a dynamic research field which has a large collection of literature base in recent years. Most of the literatures are developed into respective fields: science, technology/engineering applications, policy study and environmental concerns (refer appendix 2.3.1). There is limited number of articles angled from social science perspective. The contemporary work of "RE in social science study" is led by David Elliott. Elliott's work began in 2003[10] has been a debut, in addressing various social issues related to the RE generation and adoption. Continue in 2009, Elliott's work is expanded, contributes to the understanding of sustainable energy[11] based on different types of RE.

Even though Elliott (2003a, 2007a, 2007b) studied a small section about biomass[12], yet biofuels have not been adequately addressed. Besides, a chapter written by Scurlock (2007), discusses broadly general information about biofuels has not addressed biofuels adequately from social science angle. Hence, most of the literatures on RE/biomass have overlooked the potential of biofuels as transport fuels. Even if they do, most of the literature have been largely based on the nature science, technology and engineering (refer appendix 2.3.2).

While the next generation biofuels (NGB) is still undergoing an intensive R&D, the 1G biofuels is adopted in most of the road transport use. There are some literatures addressing the 1G biofuels execution in other countries, but not in the UK. For

10 Elliott (2003a, 2003b, 2003c) addresses the issue of world's highly dependence on fossil fuels, resulted to the rising level of CO_2 in the atmosphere. Hence, there is an urgency to develop RE which has lower environmental impacts.
11 Elliott (2007a, 2007b) correlates climate change to the prospect of RE technologies that can help society to develop a sustainable energy future. His work analyses nuclear, wind, biomass, sea and solar power from the social science perspective.
12 Biomass is a general biological substance provides energy and heat, but limitedly performs as fuel for transport. This is due to the long history of biomass (wood fuel and coal) has been used for centuries which has established a vast knowledge base.

example, the Worldwatch Institute (2007)[13] addresses biofuels production and implementation in the US, Bhojvaid's (2006) focuses at Indian agriculture, while Langeveld et al. (2009)[14] explain biofuels adoption in various parts of the world. Their publications are helpful for a general understanding. Yet, the UK would have some unique reasons and mechanisms to execute and develop biofuels. It would also face different risks and uncertainties (R&U) during these processes. Hence the adoption and localisation of biofuels in the UK are worth for further investigation.

2.3.1 Introduction

A new technology introduction into a new marketplace will face certain degrees of R&U for its development and deployment. When we look at a utility like biofuels- which are applied for the UK nationwide road transport system (the biofuels market is a whole nation), the R&U encountered are far more complicated than a consumer product introduction which has a stand in a particular market segment.

The social network for biofuels adoption and innovation is linking political, social, economic, environmental and technology (biofuels) factors-all of these are integrating and reacting within the regulated market. Through the combination of governments' intervention and the technology providers (oil companies in supplying biofuels), they are working closely to introduce biofuels blends with petrol/diesel for the UK road transport use. Hence, there are various parameters such as the market behaviour, mechanisms in driving biofuels deployment and development, R&U encountered-all of these will reflect the intricate social forces and social network involved.

2.3.2 Risk and Uncertainty Arise During Technology Development

The development of a new technology is never easy. A new technology will face a

13 Worldwatch Institute (2007) discusses the production and use of biofuels; covers not only the technical details, but also the environmental, economic and social issues mainly based in the US.
14 Langeveld et al. (2009) address the threats of climate change and peak oil crisis in driving society towards the increased use of biomass for energy. Case studies are used to demonstrate the potential of the biobased economy in different parts of the world-North America, Europe, China and Brazil.

range of technical, economic, social, political and institutional hurdles as it tries to get started on the long process of development. These constraints and hurdles have been particularly apparent in RE technologies (Elliott, 2003d).

Under the technology development, Elliott looks at the difficulties experienced by RE in trying to get funding for research by using the UK wave power programme (refer appendix 2.3.3). Besides, he studies the way which wind power has been developed around the world (refer appendix 2.3.4) through different R&D strategies. Finally, he investigates the technical problems experienced by the UK geothermal energy programme (refer appendix 2.3.5), highlights how this projects led to failure at the end.

(a) First R&U: The Research Funding

In the early stage of R&D, this is the critical time where research projects have experienced in obtaining financial support from governments. Even when it is forthcoming, the resultant projects may not always fare well and supports may not be continued. Elliott explains, most of the new technologies need financial support to get established through R&D. Yet, obtaining access to this represents a major hurdle. Inevitably, there are disagreements about which projects should be funded and how projects should be developed. Certainly, it is hard to pick a winner when technologies are at an early stage of development. In addition, there may be resistance to new developments from those with vested interests in the existing range of technologies, and lack of commitment from decision-makers to pressing ahead with what may seem like risky and long-term development (Elliott, 2003d).

(b) Second R&U: Social Acceptance

The wind turbine (appendix 2.3.4) shows how technological development interacts with social acceptance. The eventual outcome illustrates the weakness of the research-led programme, adopting "technology push" approach as opposed to being geared to responding to "market pull". Of course, in the early years there were no markets for wind turbines. However, as the markets emerged, technology push gave way to demand pull, and the Danes were in the right place to exploit this then enjoyed 90% share of the US market (Elliott, 2003d). Close involvement with users is increasingly important for successful technological innovation. Equally important is the fact that the export success of Danes was launched from a strong domestic market created from the bottom up. Around 80% of the wind turbines installed in Denmark are locally owned by individuals/cooperative guilds. Local ownership and local development have meant that funding was relatively easy to obtain as the local banks were willing to provide loans (Elliott, 2003e).

(c) Third R&U: Technical Criteria and Performance Expected

According to Paker (1991), the major technical uncertainties for geothermal technology in SouthWest England are still remaining to be overcome. The concept of reservoir stimulation to be used in the construction of a geothermal system will remain highly speculative, unless further experimental work is carried out. Besides, it is unlikely that current cost estimates of geothermal power plants could be reduced, even if the research proved successful. Studies conducted by Energy Technology Support Unit (ETSU, 1991a; 1991b) concluded that, the generation of electrical power via Geothermal is neither technically nor economically viable in the UK for the short/medium term.

Hence, the technical problems experienced by the Camborne Geothermal Project are not uncommon at the early stage of the R&D process. This is because the initial technical problems are to be expected as part of the learning process. The withdrawal of financial support may have as much to do with short-term economic considerations (Elliott, 2003d).

2.3.3 Risk and Uncertainty Arise During Technology Deployment

Overall, it seems most of the RE technologies will continue to develop and become more cost effective when time goes by. However, even the institutional support and funding are facilitated, there are many problems which RE face in trying to become established. Elliott (2003e) warns, even when the novel energy technologies have passed through the research phase, it is sometimes hard for them to get support for full scale implementation. The existing financial and institutional arrangements often do not favour/prioritise new technologies. By taking tidal power (refer appendix 2.3.6) as an example, Elliott looks at the problem of promoting energy conservation.

(d) Fourth R&U: Institutional Interests and Involvements

The economic benefits of energy conservation are clear. The RE technologies will increasingly come to the fore, as the environmental costs of existing energy technology have become more apparent. However, the pattern of deployment so far has revealed a number of major institutional problems.

A key problem facing new technologies is that, they are inevitably trying to establish themselves in an institutional, market and industrial context based on the existing types of energy technology. There are powerful vested interests in the status quo, and this is reflected in the current financial, organisational and institutional environment, which may not be well suited to the adoption of new technologies (Elliott, 2003e).

After all, energy conservation has some obvious economic advantages. Superficially, some of the RE technologies are free resources. Therefore, they ought to be commercially attractive. However, all change involves disruption and the economic advantages may take a longer time to materialise than financial backers are willing to accept. The payback time is often less in the case of energy conservation measures, but it can be serious for some RE technologies. Although the RE sources are essentially free (natural flow sources like wind, solar and wave); nevertheless, there are significant costs associated with constructing the necessary energy-conversion infrastructure (Elliott, 2003e). This is return to the root of cost-benefits analysis[15]. As can be seen, the primary problem in tidal barrages (appendix 2.3.6) was not technological, because the technology existed and was relatively mature. The problem facing the UK barrages was financial and the relatively short-term economic

15 How soon the returns would be gained? How quick the benefits could be obtained with the cost of investment is trade-off? These are the most concern issues of the decision-makers (Elliott, 2003e).

perspective that prevailed in the energy sector. Once built, barrages would pay off their investment costs in a matter of decades; they would produce very cheap electricity for centuries. However, the initial capital cost is large. As a result, investment funds proved impossible to find and the payback times were simply too long (Elliott, 2003e).

Large projects like tidal barrages clearly have problems in obtaining funding. Although smaller scale of RE products may have the attractions that they can be deployed incrementally on a modular basis, similar problems can also face them. In the past, the emphasis of major financial investment has been on the use of large scale concentrated forms of energy and managed by large scale centralised agencies. Investment agencies are therefore often suspicious of smaller projects, which are sometimes viewed as likely to be low yield investments (Elliott, 2003e).

(e) Fifth R&U: Social Acceptance

Similar to the parameter (b) discussed above, but in the context of technology deployment; social acceptance is important in the energy conservation at the domestic sector. Their success depends on the adoption of new technologies by consumers. Information can alert people what is available, but uptake has often proved to be a problem. There is still evidently a need to convince consumers of the benefits gained from RE technologies (Elliott, 2003e).

Compared to most conventional energy generation technology, wind turbines ought to have some advantages of public acceptability. They are relatively small scale and although there may be a need for fairly large numbers of them. In contrast to the hidden dangers of a nuclear plant, they have the advantage of transparency about their functionality-“what you see is what you get”. Their purpose and operation are clear from their appearance. If necessary, wind farms can be easily decommissioned/removed, returning the site to its original state.

In reality, it seems vital that the public can influence the way the RE technologies are deployed. The early enthusiasts for RE argued that, one of RE's attractions was that it could be used on the smaller scale and be more susceptible to democratic control on a local level. For local environmental impacts of “thinking globally and acting locally”, the deployments of some RE technologies are likely to be constrained by local environmental, planning and land use. Equally, the deployment of renewables may be stimulated by increasing environmental concerns over the global impacts of using conventional energy-global warming from the emission of GHGs and CO_2 produced when fossil fuels are burnt. Thus, the local and global impacts have to be traded-off against each other (Elliott, 2003e).

2.3.4 Economic versus Environmental Benefits on Renewable Energy Development and Deployment

According to Elliott (2003e), economic concerns inevitably determine the success/failure of a technological project, but land use issues and environmental concerns also enter into the commercial equation. While conventional economic factors are important, the need for a trade-off between local and global environmental factors is also important and may shape the way in which renewables are developed and deployed.

RE provides part of the solutions to global environmental problems such as combating climate change, global warming, and reducing pollutions, but no technology can be entirely benign in environmental terms. Even the cleanest solar energy also been questioned about the spaces/land use for solar farm and the disposable issues of solar panels. Although the impacts of most renewables are relatively small and localised, compared to the large and global impacts of fossil fuels, there can still be local problems. The most significant impacts are associated with large tidal barrages and hydro dams, involve large scale of engineering constructions and massive modifications to local ecosystems.

Studies of public attitudes to proposals for a barrage on the Severn estuary have indicated some mixed responses (Barac et al., 1983). There was a general enthusiasm for RE projects, and support for the local economic. However, there was concern over local impacts on wildlife and the ecosystem. Although wind farms involve less environmental modification, they also intrude on the landscape (refer appendix 2.3.7), causing significant changes in land use and social patterns. It will still be important for developers and planners to be sensitive to local concerns and to consult with local communities over the location/layout of proposed schemes. The RE technologies present system designers and planners with an interesting challenge. They must try to balance the global advantages of renewables against the local impacts, and come up with technically workable, economically viable and environmentally acceptable compromises. What seems to be needed is some way to negotiate a balance between global and local requirements (Elliott, 2003e).

2.3.5 Ten Features of a Solid Framework for Renewable Policy Design and Implementation

Mallon (2006) summarises ten key features of a successful RE policy[16] as the highlighted key factors required for the RE policy design and implemention. Each feature will be discussed respectively as below:

(a) Transparency

In order to kick-start the RE markets, support schemes and policy frameworks must be visible and accessible. In a new market, most of the potential entrants may come from the external energy companies/heavy industry. Hence, support must be transparent, accessible and open to all players to ensure that new entrants are not dissuaded from entering the market because of lacking of clarity and transparency. The best outcome for a government occurs if the maximum number of business is attracted to participate in a new industry. This will translate into high production of RE and competition to drive down prices and accelerate industry development.

16 Mallon (2006) classifies the ten key features within the framework of drivers, contexts and society. According to Mallon (2006), features one to six are driver-based issues, while seven to nine are contextual issues. The final key feature, equalization is a societal issue.

(b) Well-defined objectives

Government policies from various departments are not always fully aligned; rather it is dynamic and may contradictory. This affects a RE investment when there is inherent conflict between statements and policies. Therefore, it is important the policy should be constructed to ensure the main objectives are actually achieved. There are many objectives[17] for accelerating a RE development. From this basket of objectives, the aim is to make a framework (to align all the related policies), as conducive/specific as possible.

The next step is to prioritize these objectives. Once the list of intended outcomes is identified, the policy framework[18] must be built to ensure its actual delivery. The more specific a policy is about the RE technologies eligible for support under a scheme, the more certain will be the delivery of those technologies into the market, and the more rapid the delivery of the associated benefits/objectives.

(c) Well-defined resources and technologies

The RE technology[19] can either be defined by resource[20]/technology[21]/outcome[22], notionally referred to as technology specific[23]. Thus a decision-maker may see merit in building up some industry groups/technologies, putting others into R&D/commercialisation programmes and choosing to leave alone others which have

17 They include sustainability objectives, energy policy reform, RE production, new generating capacity, indigenous fuel manufacture, GHGs mitigation, distributed generation, increment size, energy cost and least-cost planning (internalisation), reliable energy security, new industry/manufacturing development, development of intellectual property in new technologies, job creation, rural development and nuclear phase-out.

18 the respective parameters on support, targets, prices, tax benefits, trade tariffs and milestones which need to be established.

19 We can classify RE technologies into four categories: low-cost commercial, high-cost commercial, non-commercial but with declining prices and non-commercial without declining prices.

20 Resources such as: water, geothermal, solar, wind, biomass, or sea/ocean.

21 such as wind onshore, wind offshore, solar thermal electric, solar thermal hot water and others.

22 With policies geared specifically towards RE projects implementation, a spectrum of desired outcomes may be possible. At one end of the spectrum may be a single technology policy-for example, to support solar hot water heating; while at the other end of the spectrum there may be a mix of possible technologies.

23 The advantage of being technology specific is that it becomes possible to get what is wanted in terms of technology and industry development, and can focus resources accordingly.

less long-term viability.

(d) Appropriately applied incentives

Policies intended to support renewables must permit technologies to migrate from R&D (laboratories) and to introduce into the market. Hence, financial support has to be provided where needed-according to RE's different levels of maturity.

(e) Adequacy

New renewable markets require a strong injection of resources to get them running. It is important to achieve the correct financing, duration and intensity thresholds. However, the short-term objective of commercial gain might create arguments for minimising the cost of impact of renewable, or waiting until the technology achieve its economies of scale that could take longer time to be materialised.

Since governments do not have deep enough pockets, the way to mobilise renewables is to mobilise private sector finance. The key to that is ensuring investors can get a return on their money. Thus, a good policy design will need to consider the investment profile of the RE projects and determine what is required to make the industry attractive (bankability) to private investment.

(f) Stability

Policy stability is a fundamental requirement of market certainty-which is strongly related to the production of RE and the development of the manufacturing capacity. Because policy frameworks evolve, therefore, the policy framework must have some faculty to handle change. We must ensure that the revision of RE policies will not destabilize the industry.

(g) Contextual frameworks

There are two ways to ascertain that the correct policy frameworks are present. Firstly, from a project perspective: We should put ourselves in the shoes of the business person attempting to establish a renewable production, and travel the path from project conception to project completion. We need to check every point that the project hits a contractual/legislative interaction to ensure the policies are conducive and not obstructive to RE development.

Secondly, drill down through all the levels of government and their legislative jurisdiction. Government policies with respect to large-scale renewables can come at a variety of levels. Beginning from the highest level, legislation may start with international agreements-such as the Kyoto Protocol. Then, there are national energy policy-making and state, provincial or community based initiatives.

(h) Energy market reform

Some renewables will leapfrog past conventional energy generation. However, renewables will be integrated into physical and management systems which have not been designed for this type of distributed generation.

Access to distribution is primarily an issue for renewable in a new market. Problems occur when the entities responsible for connecting RE generators have too much discretion/inadequate guidance regarding the cost requirements for connection. Hence, the approach of distributing cost over the entire consumer base may be applicable.

(i) Land use planning reform

The first step is to ensure that sufficient information[24] and adequate infrastructure[25] exist. This must be overlaid with information about potential points of environmental and social[26] impacts. Furthermore, we need to understand which types of impacts[27]

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24 Questions such as: What resources the country has? What volumes? Where they are located?

25 Questions such as: Are roads required to bring fuel in? Are major power lines required to get renewable power out? Is this infrastructure adequately mapped? How this infrastructure will affect the harnessing of these resources?

26 Considerations include population distribution, the impacts relevant to populations, optimising employment creation with location, positive/negative overlaps with other land use (farming), and issues of landscape sensitivity.

27 It is impossible to cover all impacts here. However, some of the common impacts include noise levels from wind farms at the nearest dwellings, impacts of wind farms on birds/bats, impacts of

from the technology concerned must be considered.

Much of the information will be readily available to a government. Sometimes, government may not have the information/the agencies that can do the work or it may choose not to take the lead. In these situations civil society and the renewables industry must step into the gap. If we now assume that all the information is in place to make good decisions, the next step is to establish standards/planning requirements to ensure the impacts of RE development are acceptable.

(j) Equalising the community risk and cost–benefit distribution

The environmental and energy benefits of renewables mainly accrue at a national and international level. The environmental and social direct impacts occur mainly at a local level. This discrepancy can lead to inequitable distribution of costs and benefits if they are not considered carefully.

For nations embarking on RE adoption which are signatory to the Kyoto Protocol, the benefits of the RE could be said to accrue at a national level. However, localised impacts/lifestyle adjustments will occur at the community level where the RE projects are hosted. Since these impacts can be both positive and negative, it is important to ensure that local communities get their fair share of the benefits of RE development/deployment so that they may consider themselves net beneficiaries.

2.3.6 Inductive Analysis towards Framework Construction

Reflect from Weber's work (2002), a broad range of actions can be taken by regulators to steer these RE technologies development and deployment, but only limited knowledge is available on what the actual impacts and side effects of these measures will be. There is a clear scope for improving our understanding of policy actions and of their impacts on system change in particular for any large social technology introduction. Through the inductive analysis on work advocated by

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biomass crops on local biodiversity, impacts of biomass residue removal on soil quality, effects of transport levels on local roads and communities, impacts during construction, and decommissioning arrangements.

Elliott, the researcher has extracted general concepts on causal factors from the previous RE projects discussed, and the strategies applied to have these R&U dealt along the technology development and deployment. Table 2.3.1 and Table 2.3.2 are the summaries from the literature analysis.

2.3.7 Conclusion

Learning about the past can guide us into the future. Biofuels at their early stage of deployment and development are carrying various R&U. Therefore the previous experiences are helpful in identifying the potential R&U (which biofuels are going to face), and knowing some constructive strategies in dealing with these R&U, would ensure biofuels could be executed and innovated successfully. The ten features of a solid framework have the attempt to cover the basis of a sound RE policy framework. They provide a way where the policy makers need to consider as forming a checklist for solid policy design and implementation.

Table 2.3.1: Causal Factors and Types of Risk and Uncertainty

Causal Factors of R&U	Types of R&U	
	During Technology Development	During Technology Deployment
Political supports	1. Political supports (rhetoric, lack of vision, and lack of follow through when projects are faceing with initial problems). 2. Government change (from one ruling party to another).	1. Political supports (lack of follow through when projects are under deployment).
Funding	1. Funding (inadequate, sudden budget slash from the government/private funders). 2. Short-term economic decision. 3. Require enormous investment of time, capital and resources for R&D.	1. Financial support (inadequate and discontinuous). 2. Require further vast investments of time, capital and resources for technology deployment. 3. High capital/cost, high operation cost, slow payback time. 4. Significant cost (switching cost) associated with constructing the supporting infrastructure.
Social Acceptance	1. Timing/Scenario/Contextual Setting (right time? right technology? right place?). 2. Mismatch of technical performance (scale and functions) with market expectations. 3. Disinformation, misrepresentation, prejudgement render to low appreciation on RE technology.	1. Low market acceptance on RE technology. 2. Difficult establishment of new RE technology in marketplace. 3. Economic benefits and environmental impacts. 4. Disinformation, misrepresentation, prejudgement which render to low acceptance on RE technology.
RE Technology: Between the technical criteria (performances and limitations) with expectations	1. Not understand the technical criteria of one technology (both performances and limitations). 2. Unrealistic high expectations upon technical performance. 3. Do not know how to develop a technology. 4. Asking too much too soon of an embryo technology. 5. Unclear about the future direction of one technology.	1. Mismatch between the new RE technology and the existing supporting infrastructure required. 2. Competition between this RE technology with another RE.
Institutional Interests and Involvements	1. Institutional biases/structure resistance upon vested interests, which resist the development of new technology: -Resisted/vested interests from government (pro-nuclear, pro-fossil fuels or pro RE?). -Resisted/vested interests from the industry to change to accommodate for new RE. 2. Lack of commitment from the industry. 3. Authority intervention (different roles/interests within different government departments). 4. Excuses, procrastination one technology to the future, expecting future could solve the current problems.	1. Institutional vested interests which resists the further deployment of new technology. 2. Institutional preconceptions (selective only on large scale project, suspicious on smaller projects-risky and low yield investments or vice versa).

Source: Summarised by the Researcher

Table 2.3.2: Strategies to Dealing with Risk and Uncertainty

Causal Factors of R&U	Types of R&U	
	During Technology Development	During Technology Deployment
Political supports	1. Changes of political climate (from fossil economy to green economy, combating climate change).	1. Providing supports (institutional and financial support for the full scale deployment).
Funding	1. Strong and continuous financial support 2. Eyeing for future benefits (social, economic, environmental).	1. Strong and continuous financial support 2. Eyeing for future benefits (social, economic, environmental).
Social Acceptance	1. Be realistic. Not all sophisticated technology could guarantee a market success. 2. New technology should be closer to the users (culture, economic).	1. Local ownership for strong domestic market, generating strong supports from domestic funders for the project deployment. 2. Public concerns have to be addressed and local sensitivity/reactions have to be considered. 3. Media and information dissemination.
RE Technology: Between the technical criteria (performances and limitations) with expectations	1. Do not push too far the premature technology and too soon. 2. Allow gradual process of new technology incremental developments: from R&D, innovation, moving to the full scale development and finally for commercial deployment. 3. The bottom up approach can ensure the small scale project are flexible (for accommodate any changes and further innovations), allow for piecemeal adaptation, incremental developments, obtaining feedbacks and learning from mistakes.	1. Well established of technical infrastructure in accommodating new RE technology.
Institutional Interests and Involvements	1. Converged interests and responsibilities.	1. Responsibility sharing between government and private sectors.

Source: Summarised by the Researcher

2.4 Identifying Risk and Uncertainty for New Technology Deployment and Development: A Corporate Perspective

Preface

There are two types of literature focusing on managing risk and uncertainty (R&U) from the business/management angle. Firstly, managing R&U for consumer product/technology which strongly correlates with managing innovation/new product development. Scholars like Pitblado and Turney (1996), Courtney et al. (1999), Phillips (2001), Trott (2005), Bhattacharya (2006) (refer appendix 2.4.1) shared a common ground which focuses on consumer product/technology for profit optimisation. Hence, there are tools and techniques, centred at business strategies in planning, forecasting and decision-making to deal with R&U arise that aim to reduce their implications that would depress the profitability.

Secondly, managing specific "subject" of R&U (refer appendix 2.4.2) like managing risk on construction, various projects, R&D, banking/finance/insurance and so forth. The emphasis is subjective in tackling R&U based on particular discipline.

There are limited articles about managing R&U for utility operating in a regulated market. Yet, either managing R&U for utility, consumer products or specific subjects; all of these shared a similar principle-"to avoid the occurrence of R&U", or "to resolve the R&U in oder to minimise the consequences". What make the differences depend on the types and scale of the R&U, mechanisms/strategies applied and the contexts of the R&U defined. This section presents the extracted general theories/concepts from some of the R&U literature, identify different types of R&U arise during one technology execution and innovation with counteracting strategies applied. These then could at least contribute to the understanding of managing R&U for biofuels deployment and development, from the corporate perspective.

2.4.1 Risk and Uncertainty during Technology Deployment

It is easy to assume that R&U are drastically reduced after the first commercial introduction of a new technology. Yet, Rip (1995) comments, introducing technology is not a straightforward matter, especially when the technology is new, there is no guaranteed receipe based on previous experience. Rosenberg agrees, it is true that some of the R&U have been reduced at that point. However, after a new technological capability is established, we will then see new R&U arise (as explained in section 2.2.3.1).

Since technology is an inclusive phenomenon, its deployment continues by interaction of various social and technical elements. There is no linear effect of technologies upon society, so too the conditioning of technologies by social factors is not a simple one way process. Technologies, once implemented, not only react back upon their environments, but also generate new implications (Clark and Staunton, 1989; Fleck, 1993). Rosenberg then asks: "Why is it so difficult to foresee the impact of technologically practicable applications?"

Guided by this question, Rosenberg (1994) then outlined six dimensions of uncertainty, which R&U are playing their role in technological deployment. Besides, Special Chem (2011) through its corporate report (items (a) and (b)) also delivers some of the general concerns in technology introduction.

(i) Ex Ante Uncertainty about Improvements and Uses

New technology comes into the world in a primitive condition. Often, it does with properties/characteristics whose usefulness cannot be immediately appreciated. It is inherently difficult to identify for its long-term uses. Its eventual use turns upon an extended improvement that vastly expands on its practical applications, and how rapidly it affects economy. Generally, a radical new technology must have a long gestation period before its characteristics and opportunities are well-understood and can be thoroughly exploited.

(ii) The Need for Infrastructure

New technology requires major/complete redesign and restructuring of infrastructure. This is because, a new technology-notably those which is game changing may require an entire system change to support its operation. Therefore, it needs to be perceived as having enough impact and chance to become a new standard by a large number of the industry players (SpecialChem, 2011). Firms that had huge investments in manufacturing plants, with long productive lives still ahead of them, naturally were reluctant to discard a facility that was still perfectly usable (Rosenberg, 1994).

(iii) Innovations as Competition to the Existing Technology

Major technological innovation often constitutes an entirely new technological system. The relationship between the new and the old technology would create technological competition since contemporaries of a new technology would offset certain inherent limitations of an existing one. Innovations often appear to induce vigorous responses on the firms that find themselves confronted with close substitutes for their traditional products (Rosenberg, 1994).

The SpecialChem (2011) concerns: apart from substitution, within a stiff rivalry, competitors can introduce a better performing new product/technology that could introducing a disruptive situation, setting new industry standards along dimensions on which others cannot compete. This could threaten the survival of incumbent firms. This new technology introduction, notably those which are game changing often require an entire system change. They need therefore to be perceived as having enough impact and chance to become a new standard by a large number of industry players.

(iv) Unanticipated Applications

Historically, a reason why it has been difficult to foresee the uses of a new technology is that, many major inventions had their origins in the attempt to solve very specific/narrowly defined problems. However, it is common that once a solution has been found, it turns out to have significant applications in totally unanticipated contexts[28] (Rosenberg, 1976).

(v) Impacts on Other Industries

Innovations often arise as solutions to highly specific problems in a particular industry, and their subsequent inter-industry flow is bound to be highly uncertain. In some cases, a new technological capability may have multiple points of impact on another industry.

(vi) Identification of Needs

The impacts of new technology are not just a matter of technical feasibility/improved technical performance. They are rather matters of identifying human needs, and catering to them in a novel and cost-effective way. New technology needs to pass a socioeconomic test, not just a technological one. New technology, with its eventual impact will depend on what is subsequently designed and constructed with it. What shapes it will depend on the ability to visualize how it might be employed in new contexts.

(a) Economy climate

The Special Chem (2011) highlights, macro-economic risks such as economic slowdown can delay the technology introduction. Inevitably, the passive economic climate will result in insufficient resources allocation for the technology launch and management attention. Perhaps, not many companies are adventurous enough for a massive investment at technology introduction which also could not guarantee a convincing return. Shareholders' short-term views on financial results, might force management to withdraw its support if the technology introduction/adoption is significantly slower than anticipated. Furthermore, during passive economy climate, the consumers are particular aware about expenditure. Therefore, the additional costs is one of the important factors, which could turn to be the main hindrance to execute/adopt the new technology (for both corporate and consumers).

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28 Major innovations such as the steam engine, once they have been established (initially used for pumping water out of flooded mines), have the effect of inducing further innovations and investments over a wide frontier (later became one of the power sources).

(b) Market Acceptance on New Technology

According to SpecialChem (2011), customers want to avoid risks on technology adoption: proof of reliability, scalability and future availability must be given. They want to be sure that the new technology becomes a standard in order to have backup suppliers, which reduces supply risks. They would prefer the new technology could be experienced first, during a significant time to ensure of its reliability. Customers also want to be sure that the new technology will still be there for longer time, before deciding to occur the cost and pain of a change. The benefits of technology have to be promoted. Baron (2011) suggests, mass education through media is one of the effective ways to reach the large population of the customer.

Strategically, the company has to take into account the transaction, learning and switching costs when building a value proposition to convince customers. The customer must not only be convinced that the price is good, performances and benefits are higher than the current technology; they must also be convinced that all other costs, including time, will be offset.

2.4.2 Pearson Uncertainty Map for Identifying Risk and Uncertainty in Technology Development

In view of the R&U appear along the innovation process, firms have historically, experienced high failure rates. The vast majority of attempts at innovation fail. R&U are the products and they have a number of peculiar characteristics that shape the innovation process (Rosenberg, 1994). Theses could be explained through Pearson Uncertainty Map (PUM) advocated by Pearson (1991).

PUM provides a framework for understanding the R&U in technology development at two dimensions:

(a) Uncertainty about ends (the target/output of the activity)

(b) Uncertainty about means (how to achieve this target/output)

with the classification into four quadrants (Qs) (shown in Figure 2.4.1) (Pearson, 1991). Pearson has each quardrants discussed as below:

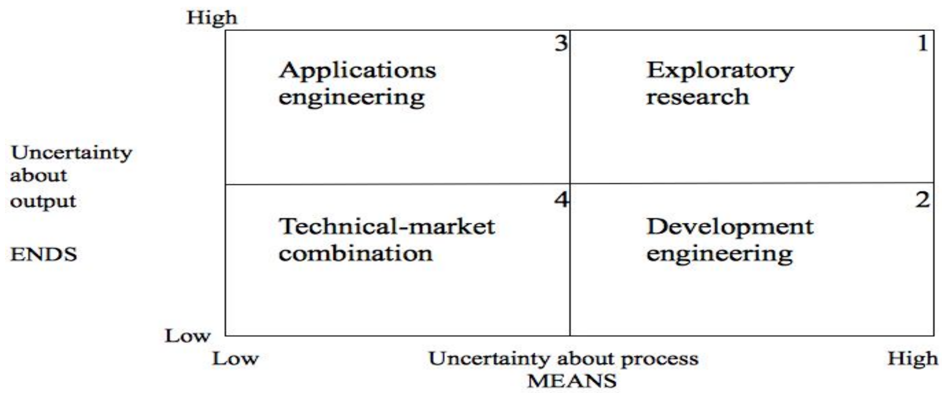

Figure 2.4.1: Pearson Uncertainty Map

Source: Pearson (1991).

(a) Quadrant 1

Q1 represents activities with high degree of uncertainty on means and ends. The ultimate target is not clearly defined, and how to achieve this target is also not clear. These activities often involve working with technology that is not fully understood, where potential products/markets have not been identified. This is largely the domain of research laboratories, usually are supported by public/private funds. The recent trends on RE development show, many research organisations and large organisations (oil/energy companies), have the necessary/rich resources embarking on exploratory study.

(b) Quadrant 2

The Q2's end is clear. Yet, how to achieve it is not clearly defined. A commercial opportunity may have been identified, but the means of fulfilling this has yet to be established. Companies may initiate several different projects centred at different approaches trying to achieve the desired product/technology. The success could only after much trying efforts and many technical difficulties need to be overcome.

(c) Quadrant 3

Activities in Q3 are those in the process is which relatively well-known, yet the outcomes are not clearly defined.

(d) Quadrant 4

It covers the type of innovative activities where the goals/outputs can be well specified and the means to achieve them are clear. The problems often arising in the area of speed: How quickly can the technical-market combination be put together (Teece, 1987; Pearson 1991).

By knowing the characteristics of each quadrants, Pearson (1991) explains, the PUM is a concept developed through working with managers from retrospective case analysis. Even though it has been briefly described, the real value lies in its ability to help identifying important characteristics in reducing the R&U of innovation.

Ideas arising from work in the Q1 may not be easily recognisable as potentially useful by those concerned with the practical aspects of managing organisations. Communication links between the explorers and the implementers need to be strong when operating within the Q1. Ideas arise in the Q4 may be exciting to the person concerned, but be seen as trivial by those who have to implement them. With the result that the innovation process is less effective than it might be, motivation can be a big challenge when working within the Q4 (Pearson, 1991).

However, creativity and innovation in the Q3 about known technologies might be most usefully exploited. The challenge is to recognise which strategies to be used to ensure the most effective implementation. The risks are frequently related to spreading resources too thinly across too many market opportunities. One of the greatest obstacles to success in innovation is the availability of choice and the consequent tendency toward indecision. Lastly, in the Q2 is an area in which innovative projects require high rewards/motivation to push the efforts in pursuing the development (Pearson, 1991).

A number of management issues are raised by the PUM. Pearson (1991) suggests that Q1 might best be left to the scientists, with cultivation instead of management being the modus operandi (Breton and Gold, 1987). People who spend much time in this type of activity (exploratory research) will probably have already built up a reputation in the area. Q2 project requires advanced technology and the transition to manufacturing is complex and requires very large scale-up. The possibilities of high rewards to the organisation at the end of the day are likely to be the major influences.

2.4.2.1 Dealing with Risk and Uncertainty during Technology Development

Fundamentally, the PUM aids to a better understanding and management of what is inevitably a complex process of technology development. The PUM addresses the nature of the R&U from two dimensions, turns to be useful since it focuses on the nature of the R&U and raises issues of technology, organisational, resources and strategies. It provides information regarding the possible need in decision-making: either to change management style, to accelerate, decelerate or even to terminate the activity earlier in order to save resources which can be used to good effect elsewhere (Pearson, 1991). The reality is, shareholders/decision makers do not have much sentimental value would emphasis on financial results, might force the management to withdraw its support if the technology development is significantly slower than anticipated (SpecialChem, 2011).

The PUM application in practice, shows its focused attention on critical issues and highlights areas for management intervention. It raises important questions about issues such as the clarity of objectives, coordination (for initial screening), management and resources commitment (for committing resources) (Pearson, 1991).

(i) Initial Screening

It provides a clear charter for corporate research. The top management must ensure that corporate research supports the firm's corporate development strategy. This requires the top management to establish an effective process for deciding which new businesses/competences the firm wants to develop. Having a clear corporate development strategy makes it easier for the top management to access the strategic importance of different research areas (Burgelman et al., 2004). Elliott (2003) agrees “most new technologies need initial R&D support to get established”. For a company which is embarking on R&D, it needs a series of reflexive analysis at initial screening to examine company readiness/capability before resources commitment (action) for technology development.

Rosenbloom and Kantrow (1982) list out factors considered by George Pake-the former vice president of corporate research at Xerox, to access technological R&U by following questions:

(a) Are the first class researchers available?

(b) Is major investment likely to yield major advances?

(c) How many years will it take before we see results?

(d) How many failures and successes have others had in this area?

(ii) Committing Resources

If a proposal survived the initial screening, resources then could be committed. Factors considered by George Pake are as following questions:

(a) Can the expert of technology be obtained through acquisition?

(b) What costs would be incurred by displacing an existing research program?

(c) Is a successful result can be transferred downstream?

(d) Will the necessary capital be available?

Clearly, answering these questions involves both qualitative and quantitative judgement/analysis. Due to the generality of these questions, they could be borrowed for common use in decision-making in the process of technology development. The messages behind these questions drawn out the factors which need to be considered such as: resources (manpower, financial), returns on investments, time, historical evidences, methodology and opportunity for commercialisation. Knowing these factors are important to limit a company's R&U exposure during the decision-making processes through screening the scenario before committing the resources.

2.4.3 Four Basic Strategies of Risk Response

Generally, R&U are the potential harm that may arise from some current process or future event (Elky, 2006). Within the research context of biofuels deployment and development in the UK, managing R&U is the process of identifying, understanding and responding to factors that may lead to failure in the biofuels implementation and innovation.

According to Elky (2006), R&U are the likelihood of a given threat-source [29] exercising a particular potential vulnerability/threats[30], and the resulting impact of that adverse event on the stakeholders. In this case we can refer to both the policy makers and the oil companies in executing the national biofuels programme and developing the next generation biofuels (NGB). Elky (2006) then adds, the principle reason for managing R&U is to protect the mission and assets of the stakeholders. However, managing R&U is not an easy task. Limited resources and an ever-changing landscape of threats and vulnerabilities make mitigating all risks impossible.

Recall the principle reason for managing R&U-a process of identifying, accessing and developing strategies to manage the R&U; Dorfman (1997) advocates, there are four basic strategies of risk response which are discussed below:

(a) Mitigation

Since the significance of a risk is related to both its probability of occurrence and its effect on the organisation, mitigation is the most commonly considered strategy. Mitigation involves fixing the flaw or providing some type of compensatory control to reduce the likelihood, or to lessen the impact associated with the flaw.

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29 either intent and method targeted at the intentional exploitation of a vulnerability, a situation and method that may accidentally trigger a vulnerability (National Institute of Standards and Technology Special Publication, 2002).

30 This is often called as threat-vulnerability pairing.
The threat is merely the potential for the exercise (accidentally trigger or intentionally exploit) of a particular vulnerability (National Institute of Standards and Technology Special Publication, 2002). Threats must be coupled with threat-sources to become dangerous. This is an important distinction when assessing and managing R&U, since each threat-source may be associated with a different likelihood, which as will be demonstrated, affects risk assessment and risk management (Elky, 2006).

(b) Transference

Transference is the process of allowing another party to accept/bear the risk on your behalf. This does not decrease the likelihood or fix any flaws, but it does reduce the overall impact on the organisation. Flanagan and Norman (1993) state: Transferring risk does not reduce the criticality of the source of the risk, it just removes it to another party. Thus, each significant risk should be considered in terms of which party should own it and who is suitable/capable for dealing it.

(c) Acceptance

Acceptance is the practice of simply allowing the system to operate with a known risk. All risks that are not avoided/transferred are accepted by default.

(d) Avoidance

Avoidance is the practice of removing the threats/vulnerable aspect of the system. It includes not performing an activity that could carry risk, or prevent an organisation to be exposed to the risk. Avoidance may seem the answer to many risks, but avoiding risks also means losing out on the potential gain that accepting the risk may have allowed.

2.4.4 Conclusion

These literatures have demonstrated some concepts for better understanding of the R&U which a company would face during a technology development and deployment. There are three identified factors, forming the R&U on technology development/deployment from corporate stand point: technology, process of innovation/business operations and market acceptance. Besides, strategies that focusing at how to overcome these R&U are also summaried, then shown in Table 2.4.1 and 2.4.2

Table 2.4.1: Causal Factors and Strategies Applied during Technology Development

Factors	R&U during Technology Development	Strategies in dealing with R&U
Factors	R&U during Technology Development	Strategies in dealing with R&U
Technology	-Uncertainty about ends	-PUM -Initial screening for company readiness/capability -Guided by the objectives to develop this technology
Process of Innovation	-Uncertainty about means	-PUM -Initial screening for company readiness/capability* -Resources commitment* *establish the infrastructure to develop the technology. Be ready to set-up the infrastructure to support the technology introduction/operation in the market.
	- Shareholders' short-term economic decision	-Understand the potential of the technology
	-Passive economic climate	-Be persistent and long-sighted if the technology is rewarding for long-term even though it is not for the time being
Market Acceptance	-The identification of needs	-Fulfil the needs
	-The expectation of technological performance	-Promote the positive characteristics/benefits of a new technology through mass education.

Source: Summarised by the researcher

Table 2.4.2: Causal Factors and Strategies Applied during Technology Deployment

Factors	R&U during Technology Deployment	Strategies in dealing with R&U
Technology	-Performances and expectations: Evaluation on the Ex ante uncertainty about improvements and uses	-Technology should perform as what has been expected.
Business Operations	-The need for infrastructure -Stiff competition (substitution, new disruptive technology) -Shareholders' short-term economic decision -Passive economic climate	-Initial screening for company readiness/capability* -Resources commitment* *establish the infrastructure to support the technology introduction/operation in the market -Be innovative to sustain technology's competitive advantage. -Be persistent and long-sighted if the technology is rewarding for long-term even though it is not for the time being
Market Acceptance	-The implications (i) Unanticipated applications (ii) Impacts on other industries -The identification of needs -Passive economic climate that influence consumers interests of technology adoption -Customer's acceptance	-Control and monitor. R&U and negative implications should be minimal as possible. -Fulfil the needs -Promote the positive characteristics/benefits of a new technology through mass education.

Source: Summarised by the researcher

2.5 Understand the Systemic Risk

Preface

Up to date, there are mainly two types of risk and uncertainty (R&U) discussed by various literatures. Firstly, the individualist R&U-the scope encompasses risk events happen on a personal scale, an organisation, a specific group/team of people, but does not apply at a larger context (entire society/nation). Most of the literatures explain the consequences on personal circumstances such as the losses of lives with accidents/injuries [31] occurred (refer appendix 2.5.1). Meanwhile, for the organisational/group/team level, the examples of R&U are the violation of law, risky projects with uncertain businesses that might lead to lives, financial/resources, reputation and time losses[32] for the organisation (refer appendix 2.5.1).

Besides individualist, some literatures address risk events at a larger scale-the society/national/international level by some of the renowned scholars [33] (refer appendix 2.5.2). They advocate the understanding of societal/national/international scale of risk events with contemporary issues, topics and case studies.

2.5.1 Definition and Conceptualisation of Risk and Uncertainty

Risk is an undesirable situation/factor involving danger/hazard, or likeliness to cause losses/injuries. A risk situation is defined, which an action will result an outcome that is not known with certainty, but the set of possible outcomes and their associated probabilities could be estimated. The risk situation is described by the analogue of flipping a fair coin. A person knows what the outcomes/probabilities are; though he/she cannot be certain which outcome will occur (Shapira, 1997; Colman, 2009a).

According to Hansson (2009), risk (in a non-technical context) refers to a situation which it is possible, but uncertain that some undesirable even will occur. In technical

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31 Adams (1995), Green (1997), Barton (2006).
32 Chapman (2006), Samociuk et al. (2010).
33 Luhmann (1991), Doughlas (1992, 1994, 2002) Leiss and Chociolko (1994), Lupton (1999, 2000), Boyne (2003), Tulloch and Lupton (2003), Ericson and Doyle (2003), Sunstein (2004), Kasperson and Kasperson (2005), Titterton (2005), Smith and Petley (2009).

uses, risk refers to something quantifiable. In decision theory (Bayesian Decision Theory[34]), decision under risk means decision with known probabilities. In risk analysis, risk often denotes numerical representation of severity, obtained by multiplying the probability of an unwanted event with a measure of its disvalue.

Meanwhile, uncertainty is defined as the state/condition of not being able to know/predict something accurately (Colman, 2009b). It is the situation when the outcome that will result from an action is unknown, or when decisions have to be made about the future is impossible to assign probabilities to the various outcomes (Moles and Terry, 1997). This is mainly caused by the limitation of knowledge about present facts or future possibilities which bring to unknown/unanticipated (Black et al., 2009a).

Knight (1921) made his famous distinction between R&U, which the former is about the randomness with objective or knowable probabilities; while the latter is about the randomness with subjective or unknown probabilities. To further distinguished risk from uncertainty, McLean and McMillan (2009) explain, the distinction is that a risky event is one where the odds can be calculated, while an uncertain event is one they cannot with no dominant strategy. Hence, derive from these explanations; risk is the factor/action leading to an unwanted situation, which the possible outcomes and their associated probabilities can be estimated. Thus there are various counteract strategies applied to deal with risk: to detect, react, resolve; (if cannot eliminate the problem totally), at least to minimise the impacts for losses.

Lindley (1971) comments, a different and more useful form of distinction are often drawn between events which are statistical (risk) and those which are not

34 Bayesian decision theory is an ideal of rationality, where definite probability value has to be assigned to each and every statement about the world that can be made in language. Non-logical propositions should never been fully believed. Hence Bayesian undertakes a complete reduction of uncertainty to probability. The crucial drawback of Bayesianism is that, it does not take into account the cognitive limitation of actual human beings. We need to reduce the prevailing epistemic uncertainty not only to probabilities, but also to full beliefs (Hansson, 2009).

(uncertainty)[35]. However, many decision situations are unique and refer to choice on one occasion, so that decision makers are not often confronted by repeatable situations. Thus, they must often make non-statistical/subjective probability assessments which are consistent/coherent in terms of the laws of probability to represent the uncertainty which exists in decision-making situations.

Under the decision theory, lack of knowledge is divided into two categories: risk and uncertainty. Risk is known with what the possible outcomes are, and what their probabilities of occurring. For uncertainty, probabilities are either unknown at all or are known with insufficient precision. The distinction between R&U is practically useful, but from a more theoretical point of view, it is unclear how to draw them in a principled way (Hansson, 2009).

Hence, the explaination above is simply to illustrate, while distinctions between R&U and statistical/non-statistical events are conceptual terms, they have limited value in the practical process of risk assessment and analysis. Indeed, concepts of risk must reflect the realities of strategic decision situations. They must recognise issues as the quality of information available to decision makers and the importance of outcomes and organisational goals. Recent literatures have classified both as the same under the risk management discipline where these terms are used interchangeably. Black, J. et al. (2009b) argued, risk is a form of uncertainty as the actual outcome of an action is unknown. Even though Hertz and Thomas (1983) and Renn (2008a) aware some earlier writers drew a distinction between R&U, they conclude risk also means both uncertainty, and the results of uncertainty.

2.5.2 Theoretical Positions of Risk

As risks become complex and uncertain, the formalised systems for assessing and managing them become more pervasive. Although the dominant definition of risk in contemporary society adheres to a positivist notion of validity, risk theory presents

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35 Statistical events are defined to be capable of very extensive repetition, whereas non-statistical events are essentially unique (Lindley, 1971).

often competing ideas what constitutes risk. The differentiated forms of discourse which have been developed in relation to risk are based upon a number of theoretical positions (Flynn, 2007). Denney (2005) has examined risk from the six positions shown in table 2.5.1.

The forms of analysis described above, present the notion of risk from distinctive standpoints and lead to the formulation of a number of partially answered questions. Individualists ask "How people perceive risk and the frequency of risk?" "Are errors in judgement about the likelihood of risk predictable?" "Is it possible to understand the cognitive processes underlying such judgements?" (Colledge and Stimpson, 1997). Douglas (1966) then widens the discussion of risk to encourage the consideration of some social scenario. Since early writings in the mid 1960s, she asked "Why some communities regard some social phenomena as constituting a risk while others are not?" Douglas then concluded: the ideas about risk are culturally created according to different communities.

The socially constructed risk has subsequently influence the phenomenological analysis, which risk perceptions are socially constructed, while the phenomena and pervasiveness of the risk consequences are taken place through social interaction. In this modern day, Beck (1992) who advances "risk society" advocates, individuals are constantly seeking to come to terms with uncertainty through a contested form of scientific rationality[36]. Hence, insecurity from this perspective on the modern society forms the basis for a "risky" society. Finally, the governmentalist approaches which focus on the relationship between authority and risk with how political authority and governance system attempt to control/manage risk (Denney, 2005).

Denny (2005) then draws some of the limitations in all of these approaches. While the individualistic approaches fail to take an account of the complexity of risk, the culturalist and phenomenological explanations have not taken sufficient cognisance

36 Why have individuals become responsible for anticipating and negotiating risks? Why risks are unknown and unpredictable as technology takes a global grip? Can I believe the expert who tells me that it will be effective and safe? (Beck, 1992).

of the environmental and structural problems which risks are conceptualised.

Table 2.5.1: Theoretical Position of Risk

Six Positions	Theoretical base	Definers of risk	Policy implications	Explanation of emergence of risk	Criticisms of position	Applications
1.Individualist position	-Probability theory	-Experts	-Need for individual risk assessment to be structured into institutional activities	-Risk is calculable -Risk is an independent variable	-Socially and culturally decontextualised	-Scientific risk analysis -Insurance industry -Scholars: Thomas B., MacDonald, K.; MacDonald, G.
2.Culturalist position	-Social anthropology -Structural functionalism -Social constructionism	-Ideas about risk and danger are culturally created by communities	-Policies must take account of cultural (moral, aesthetic and political foundations) to understand risks	-Reality is mediated through political need for a forensic approach to risks	-Static structural functionalism -Too little attention is paid to future social developments	-Poverty -Globalisation -Scholar: Douglas, M.
3.Phenomeno-logical position	-Phenomenology -Perceptions are socially constructed -Phenomena is through social interaction	-Individual construction	-Strategic intervention is required in relation to phenomena designated as constituting highly relevant risk	-Emergence of traditional and post traditional society -High modernity -Reflexivity	-Can be used for the purposes of analysis	-HIV/AIDS infection -Scholars: Schutz A., Bloor M.
4.Risk society position[37]	-Risk society -High modernity -Reflexivity	-Experts	-Third way combination of private with public -State should provide protection against risks according to needs -Socially inclusive to reduce risks	-High modernity	-Essentialised over emphasis on risk -Fail to capture the fluidity of risk, which is elusive and constantly changing its form	-Traditional capitalist society has changed towards late modernity/post-modernity. -Welfare, environmental movement, employment/ unemployment, crime -Scholar: Beck U., Giddens A.[38]
5.Postmodern position	-Post-structuralism -Postmodernity -Governmentality	-Experts	-Increasing use of surveillance to govern individuals and aggregate population groups -State claims to be working to protect the population from risk	-The tendency to deconstruct the subject, and the creation of calculable heterogeneous elements which constitute risk	-There is an over concentration on deconstructing what exists and an under emphasis of the real risks	-Preventative policies, moral obligation, -Scholar: Foucault M., Castel, R.
6.Regulatory position	-Systems -Organisational theory	-Bureaucrats -Politicians -Media	-Creation of systematic mapping and describing of risks	-Differentiated causation, including natural, social and manufactured	-There is an over emphasis on systems -De contextualisation	-Hood, et al.[39]

Source: Denney, D. (2005). pp. 15-16.

There are dangers in regarding the emergence of a risk society as the result of a historical logic, since risk has been uppermost in the minds of citizens throughout

37 Beck (1992) emphasis on reflexive modernisation and introduced the concept of risk society to denote a special stage, which the nature of hazards and their lack of temporal and spatial limits, are profoundly different from previous eras. New inequality is created, a crisis of credibility and trust is taken place. These risks are man-made hybrids, combining cultural definitions, technologies, politics and mass media. Beck (1998) argues, we no longer choose to take risks as we have them thrust upon us. Thus, for Beck (2000), risk discourse begins where trust in security and belief in progress end and uncertainties are manufactured. Paradoxically, science and technology solved major problems, but also (albeit unintentionally) produced new hazards.

38 Giddens (1991) argues that modernity is a risk culture. The concept of risk has become an organising concept for lay actors as well as experts. People have become more reflexive, questioning risks but also embracing some of them.

39 The notion of risk regulation regime is meant to denote the complex of institutional, rules, practice and ideas that are associated with the regulation of a particular risk/hazard (Hood et al., 2001).

history. Furthermore analyses of risk based upon the governmental perspective are narrowing, which do not give appropriate recognition to the reality of risk in everyday life.

Numerous commentators have repeatedly stressed the ambiguous, contested and opaque character of the concept of risk. It is not surprising that, there is such an enormous scholarly and technical literature about different aspects of risk (Flynn, 2007). However, Renn (2008a) advocated, these different positions of risk could be grounded from two perspectives: the social constructionism versus the realism of risk.

2.5.3 Social Constructionism versus Realism of Risk

According to Renn (2008a), all concepts of R&U have one element in common: the distinction between possible and chosen action. At any time, an individual/organisation/society, faces several options for taking action (including doing nothing), which is associated with potential negative consequences. The term "R&U" denotes the possibility that an undesirable state of reality/adverse effects may occur as a result of natural events/human activities. This definition implies that humans can/will, make casual connections between actions. They can be altered, either by modifying the initiating activity/event, or by mitigating the impacts. Hence, the definition of R&U contains three elements:

(a) Outcomes that have an impact upon what human value;

(b) The possibility of occurrence (uncertainty); and

(c) A combination of both elements mentioned above.

There are debates about the nature of risks: Is risk social constructed or is a real phenomenon? The issue is whether technical risk represents "objective" probabilities of harm, or only reflects the conventions of an elite group may claim no more degree of validity/universality. Besides, different cultures may have different mental representations of what they regard as R&U, the magnitude and the probability of harm. On the first glance it is obvious that risk constitute mental models (OECD, 2003). Different stakeholders involved, creatively arrange and reassemble signals that they get from the real world, and then provide structure and guidance to an ongoing process of reality enactment. Therefore, risks represent what people observe in reality and what they experience. The link between risk as a mental concept and reality is forged through the experience of actual harm, as the consequences of risk (Renn, 2008a)

The status of risk as a mental model has major implications for how risk is perceived. Although societies have gained experience and collective knowledge of the potential impacts of events/activities, one cannot anticipate all potential scenarios and be worried about all the potential consequences of an activity/event at all the time. Besides, it is impossible to include all possible options for intervention to avoid R&U. Therefore, societies have been selective in what they have chosen to be worth considering and what to ignore (Douglas, 1990; Thompson et al., 1990; Beck, 1994). Specialised social organisations such as social movements/environmentalists have been established to monitor the environment for hints of future problems, and to provide early warning of some potential future harm. This selection process is not arbitrary, rather guided by cultural values and institutional arrangement (Renn, 2008a).

Meanwhile, the technical risk analyses rest on many conventions (Weinberg, 1972; IRGC, 2005), such as the selected rules to identify undesirable effects, the choice of probability and the equal weighting of probability and magnitude. All of these conventional risk analyses can be defended through logical reasoning; but they represent only parts of what individuals and society experience as risk. This does not mean the technical risk analyses are unnecessary/less relevant, because they do serve a major purpose (Shrader-Frechette, 1991). Technical risk analyses help decision makers to estimate the expected physical harm. They provide the best knowledge about actual damage that is logically/empirically linked with each possibility (NRC, 1983).

Kasperson et al. (2005) explain, the technical concept of risk is focused on the probability of events and the magnitude of specific consequences. Clearly, other aspects of the risk such as familiarity with the hazard/catastrophic would shape the public responses (Slovic et al., 1982). Hence, the technical concept of risk, according to Kasperson et al. (2005) is narrow and ambiguous. Even though the technical concept of risk aggregates data over space, populations and time; the undesired effects are still being confined to physical harm (to humans and ecosystems). The narrowness of this approach constitutes both weakness and strength.

Abstracting a single variable from the context of risk taking, makes the concept of risk one dimensional. While, confining undesirable consequences to physical harm excludes other consequences (like cultural change) that people might regard as undesirable. However, the main emphasis on physical harm may be the only consequence that almost all social groups and cultures agree to be undesirable (HMSO, 1988; Kasperson, 2005).

Therefore, the next few questions are: "How to define, and balance the interpretation of a large scale societal risk event, from both social constructionism and realism points of view?" "What should be considered, and how we should react to the expected versus unexpected societal risk event?" For example, climate change is a known societal risk event supported by the realism and social constructionism. Meanwhile, some unanticipated R&U due to a large technology application (like biofuels adoption for nationwide transport system) are rather uncertain. Hence, both expected and unexpected R&U for societal risk event would have a strong correlation on probability theory, but should be wider than the individual risk implications. They would have a societal scale of risk, yet should be more than merely cultural and phenomenological since the risk consequences are tangible. They ought to have the governmental and regulatory participation, but to deal with emerging R&U they would require more than just the political involvement rather the relevant stakeholders to have the R&U solved. Besides, for unexpected R&U, it would not allow a well-planned preventive method to be set in place beforehand, rather an impromptu strategy is needed to confront with any dynamic changes. Therefore, the concept of systemic risk has to be taken in, because it could enrich the existing six theoretical positions, and widen the understanding of new form of large scale societal risk.

2.5.4 Introduction to Systemic Risk

Krechowicz and Fernando (2009) contextualise "emerging risk" as eight [40] environmental trends and their impacts on three key sectors[41]. Although they do not entirely define the term of emerging risk, yet the idea has been built on the large scale of the R&U that associate with environment consequences. Another two definitions on emerging risk are provided by Barney (2009), and Jourdan and Michalson (2010).

According to Barney (2009), emerging risks involve a high degree of uncertainty because they do not have a track record which can be used to estimate the likeliness of probabilities and expected losses. Meanwhile Jourdan and Michalson (2010) define emerging risk as a large scale event/circumstance which is hard to predict, beyond any particular party's capacity to control. It may have large impacts not only on the organisation but also on multiple stakeholders across geographic borders, industries and sectors.

The OECD (2003) report contextualises systemic risk based on five large risk clusters[42]. The report defines systemic risk as any risk in a larger context of social, environment and economic consequences. It is driven by natural events, human action, economic, social, technological developments or policy actions, which takes place at national/international level. These driving forces will reshape conventional

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40 [1]deforestation, [2]water scarcity, [3]climate change, [4]food security, [5]energy security, [6]air pollution, [7]urbanisation, [8]population growth.

41 Krechowicz and Fernando (2009) research is connecting eight environmental trends to the investment decision-making process, to demonstrate how these trends affecting three sectors (food and beverage, power generation and real estate). This is aimed to help investors and analysts to assess the trends' financial impacts on company valuations.

42 [1]natural disasters, [2]technological accidents, [3]infectious diseases, [4]terrorism related risks, [5]food safety.

hazards and create new ones with bigger amplitude, modify vulnerability to higher frequency of R&U, spread the negative impacts and alter society's responses. The International Futures Programme (2009) explores implications of the economy and social developments in the 21st century, focusing on the possibility of major systems becoming more vulnerable in the future. Sectors like transport, energy, food are all examples that could be severely damaged by a single catastrophic event or chain of events.

The emergence of systemic risk advocated by the OECD's (2003) and the International Future Programme (2009), have opened-up the tunnel view in defining risk, more than the polarised constructivist or realist perspectives. The combination of these two views is important to provide an understanding of what systemic risk is about. The systemic risk which is considered as a large scale of R&U with widespread implications could affect a society on many aspects such as: public health, food supply, security, environment and others (refer appendix 2.5.3).

2.5.5 Limitations of the Existing Models in Managing Systemic Risk

According to OECD (2003), limitations of conventional risk management (RM) are likely to lead to difficulties in dealing with systemic risk. This is justified by four reasons:

(a) Existing risk assessment/management is based on models, which are sometimes far from reproducing real world conditions accurately. In many risk areas, the model is a recording of past occurrences/cases, rather than a formal evaluation of the various upstream interacting processes influencing risk. Besides, in a context where underlying conditions are changing, past experience in dealing with R&U might be misleading.

(b) Most models assume a more or less linear relationship, linking a hazard from a well identified source to a single endpoint of solution. This simplification appears to be inadequate to explain and resolve complex phenomena.

(c) The long-term consequences and impacts of the risk assessment/management system studied are usually neglected. This is because the system is assumed to be self-contained in space at physical, operational and time, to simplify the resources/strategies applied in counteracting with the R&U.

(d) Human behaviour is a prevailing risk factor, but is difficult to evaluate as the social interaction are dynamic. Faced with these difficulties, the existing RM often uses simplistic/standardised models of behaviour.

As such, risk assessment/management must recognise the plurality of factors involved which cause the risk to be happened. This means that risk assessment/management will need to combine knowledge coming from a larger variety of disciplines and areas of expertise, and pay increased attention to changing conditions. On a technical level, improved methods are gradually emerging, with integrated approaches that can deal with interactions and non-linearity; probabilistic methods that allow variability and uncertainty to be incorporated; and information systems that can provide socioeconomic data help manage information for effective decision-making (OECD, 2003).

2.5.6 A Comprehensive Risk Management: The Risk Governance

The OECD (2003) mentions the concern of the conventional RM framework, should encompasses a larger context of analysis. This could then provide a bigger overview, during the analysis, assessment and appraisal, towards the effective strategies applied. To capture the RM paradigm, adequate understanding of a given risk through analysis, assessment and appraisal are not an end in itself, because these methods are providing inputs for decision-making. In reality, the decision maker is pressured to determine the level of risk from the community's standpoint, many times in a situation where resources are limited and scientific understanding of the issue may be incomplete while opinions and interests are contradicted. Therefore, as systemic risk emerged, the RM could gradually become extremely challenging.

Thus, OECD (2003) highlights:

(a) It is important that resources for risk reduction are allocated efficiently. Rationalising the use of resources is often hampered by scientific uncertainty and the absence of consensus in society as to the value issues involved.

(b) Risk assessment has to deal with various kinds of uncertainty. Due to the complexity of causal relations and gaps in data, emerging systemic risk often can involve large gaps in the understanding of the phenomena at work. This kind of uncertainty often goes hand-in-hand with scientific controversy, which is extremely difficult for related stakeholders to address.

(c) The proponents of a technical approach to RM have long considered that the public's perceptions were unfounded. At the same time it is increasingly accepted that although the public perception of risk can be wrong-biased and mislead by the amplifications of media. Risk has a multitude of dimensions, some of which involve ethical considerations. A number of different views can thus be pertinent and legitimate.

To address these issues, decision-making tools and processes, need to clarify the respective contributions of facts and uncertainties. They also need to satisfy more than one objective (using resources efficiently, meeting public expectations), and often in a situation where the different objectives are competing. It is possible to develop a framework for dealing with R&U, conflicting values and interests while trying to maintain consistency (OECD, 2003).

2.5.7 Conclusion

The systemic risk is a new form of a large scale R&U, which has widened the conventional theoretical positions. Inevitably, it is the consequence of risk society and modernisation. The combination of realist and constructivist could bring better understanding of it. Since it is a new type of risk, it requires new strategies to assess/manage at both expected and unexpected R&U which it might bring.

The RM framework to deal with systemic risk should be an unconventional one. According to OECD (2003), the framework should use a combination approaches. First, it endeavours to tackle the issue of systemic risk in a future oriented manner, by examining the trends and driving forces shaping the risk landscape. Second, it looks at the vulnerability of vital systems (energy, transport), to identify any gaps that allow the systemic risk to be appeared. Third, it examines a broad range of expected and potential yet unexpected risks across the entire risk assessment cycle, aiming for a holistic approach.

Hence, the risk governance (RG) framework advocated by Renn (2008), could fulfil many of the criteria required, not only to deal with conventional/expected risks, but also a large scale and unexpected systemic risk. The RG framework will provided a comprehensive analysis from the activities of pre-assessment, risk characterisation/evaluation, risk appraisal to RM while risk communication linking these four activities in soothing information exchange (will discuss in section 2.6). Besides, Renn (2008) RG framework is one of the up-to-date method in managing risk. The framework's action oriented is applicable for any decision makers either from the public/private sectors. It helps to draw out conclusions in particular, emerging systemic risk which requires a systematic responses and measurements.

2.6 Risk Governance: Dealing with Risk and Uncertainty Systematically

Preface

There are three reasons why Renn (2008a) risk governance (RG) framework is selected for the literature analysis. Firstly, the conventional risk management (RM) literature are much explaining on each of the functions-risk assessment, risk perception, risk communication and RM independently (refer appendix 2.6.1); rendered to significant overlaps exists among each of these functions. Renn (2008a) advocated the concept of RG. It is a framework which pulls in five functions ([1]pre-assessment, [2]appraisal, [3]characterisation/evaluation; [4]management; while [5]risk communication integrating all four activities) to deal with R&U.

Secondly, some of the RM literatures favoured the quantitative analysis[43] (Korath, 1998; McNeil, 2005; Vose, 2008) (refer appendix 2.6.2); while some are prone to the qualitative analysis[44]. Certainly, there are literatures that combine both methods in order to enhance the validity/accuracy for decision-making. The RG framework is central on the qualitative approach which suits the nature of this research.

Thirdly, many of the suggested strategies (from various RM literatures) are specifically defined. They are based on the respective "subjects" of the R&U (refer appendix 2.4.2), which have the specific contexts for application. Conversely, Renn's RG general framework which is constructed from the social science/management perspective, could be applied at many organisations either private/public sector. Through inductive/deductive analysis, the framework helps to identify, evaluate the risks while justify the counteracting strategies for better decision-making. Renn (2008a) advises, RG framework should not be seen as the sequential steps, rather as elements that are closely interlinked. The main objective from the framework is to standardise procedures/techniques, to enhance the spectrum of risk events that can be modelled, and to ensure that R&U are understandable and could be dealt in a

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43 emphasises on measurements to drive decisions, such as cost-benefits analysis, probability analysis, statistical analysis, ratio projection and model simulation

44 The "subjectiveness" and the interpretations of qualitative R&U are varied. It is designed to provide detailed/rich descriptions, to enhance one's awareness of potential R&U.

systematic way.

2.6.1 System Structures of the Risk Governance Framework

Governance is described as a structure/process for collective decision-making, involving the governmental/non-governmental actors (Nye and Donahue, 2000). Governing choices in a modern society is the interplay between governmental institutions, private companies, non-governmental organisations, socioeconomic forces and other civil society actors (Renn, 2008a). Therefore, RG involves the translation of the substance and core principles of governance to the context of understanding R&U and decision-making.

RG requires the consideration of legal, institutional, social and economic contexts, which R&U are evaluated, through the involvements of the related stakeholders. RG looks at the complex web of actors, rules, conventions, processes and mechanisms concerned with how risk information is collected, analysed, communicated; and how management decisions are taken. Encompassing the combined decisions and actions of both governmental and private actors, the RG signifies the nature of a risk requires the collaboration/coordination among stakeholders. RG, not only includes a multifaceted, multi-actor risk process, but also calls for the consideration of the contextual factors such as institutional arrangements[45] and political culture (Renn, 2008a).

2.6.2 Four Phases of the Risk Governance Framework

The RG framework will be directed by relevance claims[46], evidence claims[47] and normative claims[48]. The framework proposed consists of: pre-assessment, appraisal, characterisation/evaluation, and management; while the risk communication accompanies all four activities. It has transformed the linear structure which

45 The regulatory and legal framework that determines the relationship, roles and responsibilities of the actors, and the coordination mechanisms such as markets and incentives (Renn, 2008b).
46 What matters to society? What are important phenomena that should receive our attention? (Renn, 2008b).
47 What are the causes? What are the effects? (Renn, 2008b).
48 What is good, acceptable and tolerable? (Renn, 2008b).

commonly found in other comtemporary conceptions of RM (RCEP, 1998; Prime Minister's Strategy Unit/UK Cabinet Office, 2002) into an iterative/interlinked process, shown in figure 2.6.1.

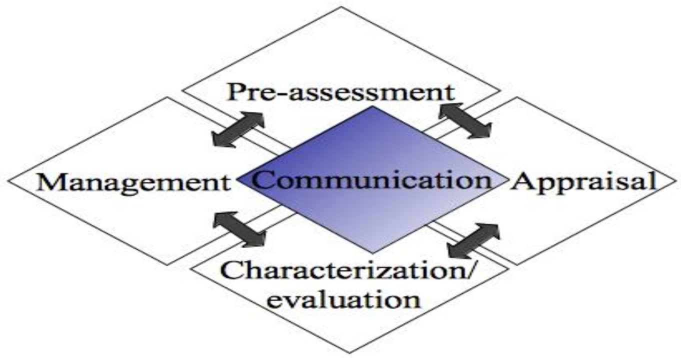

Figure 2.6.1: The RG Framework
Source: Renn (2008b) pp. 48.

2.6.2.1 Pre-assessment

In this stage, the risk event is framed/defined. This needs to be governed by societal values and inspired by what we have known about the hazard (Zinn and Taylor-Gooby, 2006). It starts with an identifying of major societal actors related to the risk event. They could be the causers of risk, the problem solvers, or those who might be affected by the risks; such as the governments, the companies, the pressure groups and the general public. Then, values from the stakeholders and risk evidences have to be investigated. This is because values are shaping the interests, risk perceptions and concerns of the different stakeholders (Renn, 2008b), while the evidences are the realism of risk consequences.

The second part of the pre-assessment concerns the institutional means of an early warning and monitoring. This task refers to the institutions of government, business and civil society to identify unusual events/phenomena, to detect new emerging R&U and to provide some initial insight into the extent/severity of these R&U. Risks information is pre-screened and allocated to different assessment and management routes. Sometimes in a crisis situation, management actions may need to be taken before any assessment is even carried out. Renn (2008b) concludes four components of the pre-assessment (refer appendix 2.6.3), which are useful when accessing risks.

2.6.2.2 Appraisal

The risk appraisal has two stages: Firstly, technical scientists use their skills to produce the best estimation of the physical harm that a risk may induce. Secondly, social scientists and economists will identify and analyse the issues that individual/society links with risk. Considering the results from the pre-assessment, then investigate/calculate the socioeconomic implications of risks; all of these are intended to produce the best possible scientific estimate of the physical, economic, social and environmental consequences of a risk event (Renn, 2008c). Meanwhile, appraising risks is confronted with three challenges: complex, uncertain and ambiguous (refer appendix 2.6.4). These three challenges are not related to the intrinsic characteristics of risks, but to the state and quality of information/knowledge available about risks.

2.6.2.3 Characterising and Evaluating Risk

There are two aspect of risks, the tolerability[49] and acceptability[50] of a risk (HSE, 2001) (refer appendix 2.6.5). By examining the resulting risks as a function of vulnerabilities, a judgement on tolerability and acceptability regarding to the selection of protective measures becomes meaningful (Renn, 2008d). Hence the evaluation is directed three different kinds of deliberations:

(a) Deliberation on the results in consideration of wider socioeconomic factors: societal needs, quality of life, risks-benefits balance, social mobilisation, potential of conflict resolution, political priorities, legal requirements and policy imperatives;

(b) To arrive at a judgement on tolerability and acceptability, based on balancing pros and cons, trading-off of different (competing/conflicting) preferences, interests and values;

(c) Taking into account the individual and social benefits, associated with the risk-

49 Tolerable, refers as worth pursuing for the benefit that it carries; yet requires additional efforts for risk reduction (HSE, 2001).

50 Acceptable refers to an activity where the remaining risks are low, that additional efforts for risk reduction are not seen as necessary (HSE, 2001).

bearing technology and activities, testing potential socioeconomic and environmental impacts, discussing different development options for the economy/society, and weighing the competing arguments/evidence claims in a balanced manner (Renn, 2008d).

2.6.2.4 Risk Management

Risk management (RM) refers to the creation/evaluation of options for initiating/changing human actions, or structures with the objective of increasing the net benefit to the human society and preventing harm to what they valued. The identification of these options/evaluation is guided by a systematic/experiential knowledge gained, which prepared by the experts and stakeholders. However, we may also need to act in some situations which are lacking/insufficient of knowledge/information about potential outcomes of human actions. The most complex questions emerge when one looks at "how" society and its various actors managing a risk.

This is because the decision-making structure of a society is highly complicated/fragmented. Apart from the structure itself, the people/organisations that share the responsibility for managing a risk must also consider the need for the sufficient organisational capacity to create the necessary knowledge, and to implement the required actions to accommodate political, cultural norms, rules and values within a societal context, and the subjective perceptions of individuals and groups (Renn, 2008e). On the other hand, Hammond, et al. (1999), Morgan (1990; 1995), Keeney (1992), Aven and Vinnem (2007) have discussed and provided some new inputs on six classic decision theories (refer appendix 2.6.6).

2.6.3 Risk Management-Strategies Based on Risk Characteristics

Using the distinction between complexity, uncertainty and ambiguity; it is possible to design a set of generic RM strategies to four risk classes, which would enhance the efficiency of the strategies. The choice of the RM strategies not only depend upon the risk characteristics, but also the type of risk and the risk context (Renn, 2008e).

The appendix 2.6.7 has summarised these four classes; yet, the brief explanations are shown as below:

(a) Linear/routine risk problems[51]

The risk event requires hardly any deviation from the traditional decision-making. Data are provided by statistical analysis, and goals are determined by law/statutory requirements. The role of RM is to ensure that all risk reduction measures are implemented/enforced. Traditional risk-risk comparisons, risk-risk trade-offs, risk-benefit analysis and cost-effectiveness studies are the instruments of choices for finding the most appropriate risk reduction measures. Additionally, risk managers can rely upon best/effective practices, upon trial and error. However these simple risks should not be equated with small/negligible risks. The major issues here are the potential negative consequences are obvious, the values applied are non-controversial and the remaining uncertainties are low (Renn, 2008e).

(b) Complex risk problem

Complex risks are often associated with major scientific dissent about complex dose-effect relationships, or the alleged effectiveness of measures to decrease vulnerability. The objective for resolving complexity is to receive a complete and balanced set of risk and concern assessment results that fall within the legitimate range of plural truth claims (Renn, 2008e).

In a situation where there are no complete data, the major challenge is to define the factual base for making RM and regulatory decisions. The main emphasis is on improving the reliability/validity of the results that are produced in the risk appraisal. They may not get a single answer, but they might be able to get a better overview of the issues of scientific controversy. If input variables to decision-making can be properly defined/affirmed, risk characterisation and evaluation can be done on the basis of risk-benefit balancing and normative standard-setting. Traditional methods

51 Examples of linear risk problems: accidents, known food and health risks and also regularly recurring disasters (Renn, 2008e).

such as risk-risk comparison and cost-benefit analysis are well suited to facilitate the overall judgement for placing the risk in the traffic-light model (acceptable, tolerable or intolerable). These instruments provide effective/efficient/fair solutions with regard to finding the best trade-off between opportunities and risks (Renn, 2008e).

(c) Risk problems[52] due to high uncertainty

If a high degree of uncertainty remains, RM needs to incorporate hazard criteria, including aspects such as reversibility, persistence, ubiquity, and select management options that would empower a society to deal with the worst-case scenarios. It seems prudent to take a precautionary approach when managing risks characterised by multiple/high uncertainties. Since unresolved uncertainty implies that, the true dimensions of the risks are not yet known, one should pursue a cautious strategy that enables learning by restricted errors. The main philosophy for managing this risk is to allow small steps in implementation (containment approach) that enable risk managers to stop or even reverse the process (Klinke and Renn, 2002).

(d) Risk problems due to interpretative and normative ambiguity

Generally, risk information is interpreted differently by different stakeholders in a society. This is due to different viewpoints about the relevance, meaning and implications of factual explanations/predictions; for deciding the tolerability and acceptability of a risk event. If the values and priorities of what should be protected/reduced are subjected to an intense controversy, RM needs to address the causes for these conflicting views (von Winterfeldt and Edwards, 1984). Thus, RM should initiate a broader societal discourse, to enable a participative decision-making. These discursive measures are aimed at finding appropriate conflict-resolution mechanisms, which capable of reducing the ambiguity to a manageable number of options that can be further assessed/evaluated (Renn, 2008e).

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52 Examples of risk problems due to high uncertainty: contamination, radiation or pandemic (Renn, 2008e).

2.6.4 Risk Communication

Risk communication (RC), according to Renn (2008f) investigates how expert assessments could be communicated to the public best. Then Leiss (1996) has identified three phases in the RC practices:

(a) The first phase: the necessity of conveying the probabilistic thinking to the general public, and to educate the laypersons to acknowledge/accept the RM practices from the respective institutions. However, there is a possibility where people were unwilling to abstract from the context of risk taking, and they might reject the reliance on expected values as the only benchmarks for evaluating risks. When this attempt at communication failed, phase two was initiated.

(b) The phase two: to emphasis persuasion and focus on public relations in order to convince people that public worries/concerns about risk events were regarded as overcautious. However, it did not convince a majority of the people that the current RM practices were politically appropriate response. This one-way-communication will produce very little effect. Most respondents were appalled by this approach or simply did not believe the message, regardless of how well it was packaged; as a result, phase three has to launch (Renn, 2008f).

(c) The phase three: stresses a process of two-way-communication which, not only the members of the public who are expected to engage in a social learning process, but the risk managers as well. The objective is to build up mutual trust by responding to the concerns of the public and relevant stakeholders. The ultimate goal is to assist the stakeholders to understand the rationale of risk assessed results and the RM decisions taken, and to help them to arrive at a balanced judgement that reflects the factual evidence about the matter at hand on their own interests and values (OECD, 2002).

Good practices in RC help the stakeholders to make informed choices about matters of concern to them and to create mutual trust (Hance et al., 1988; Lundgren, 1994; Breakwell, 2007). Although RC implies a stronger role for risk professionals to provide information to the public rather than vice versa, it should be regarded as a mutual learning process in line with the requirements postulated. Hence, effective RC has a major bearing on how well people are prepared to face/deal with risk.

There are four functions of RC (Morgan et al., 1992; OECD, 2002):

(a) Education: inform the audience about risks.

(b) Risk training and inducement of behavioural changes: help people to deal with risks and the way in handling.

(c) Creation of confidence in institutions responsible for the assessment and RM: give people the assurance that the existing RG structures are capable of handling risks in an effective, efficient, fair and acceptable manner.

(d) Involvement in risk-related decisions: give stakeholders and representatives of the public the opportunity to participate in the risk appraisal and management efforts, or be included in the resolution of conflicts about risks and appropriate RM options.

2.6.5 Conclusions

The RG framework builds on the logical structure of four activities (pre-assessment, appraisal, characterisation/evaluation and management, while risk communication is connecting all four activities). This framework is in line to ensure the compatibility with professional codices and practices (refer figure 2.6.2). According to Renn (2008g), the RG framework could help to identify the key steps in the RG process, and the diagnosis of potential causal factors, lead to complex, uncertain and ambiguous R&U. In addition, the framework assists in facilitating a thorough understanding of the R&U issues, identifying the stakeholders concern with the R&U and providing guidance for how to include stakeholders in the processes.

The RG process includes the matters of institutional design, technical methodology, administrative, consultation, legislative procedure and political accountability on the public bodies; with corporate responsibility and strategy on the private enterprises.

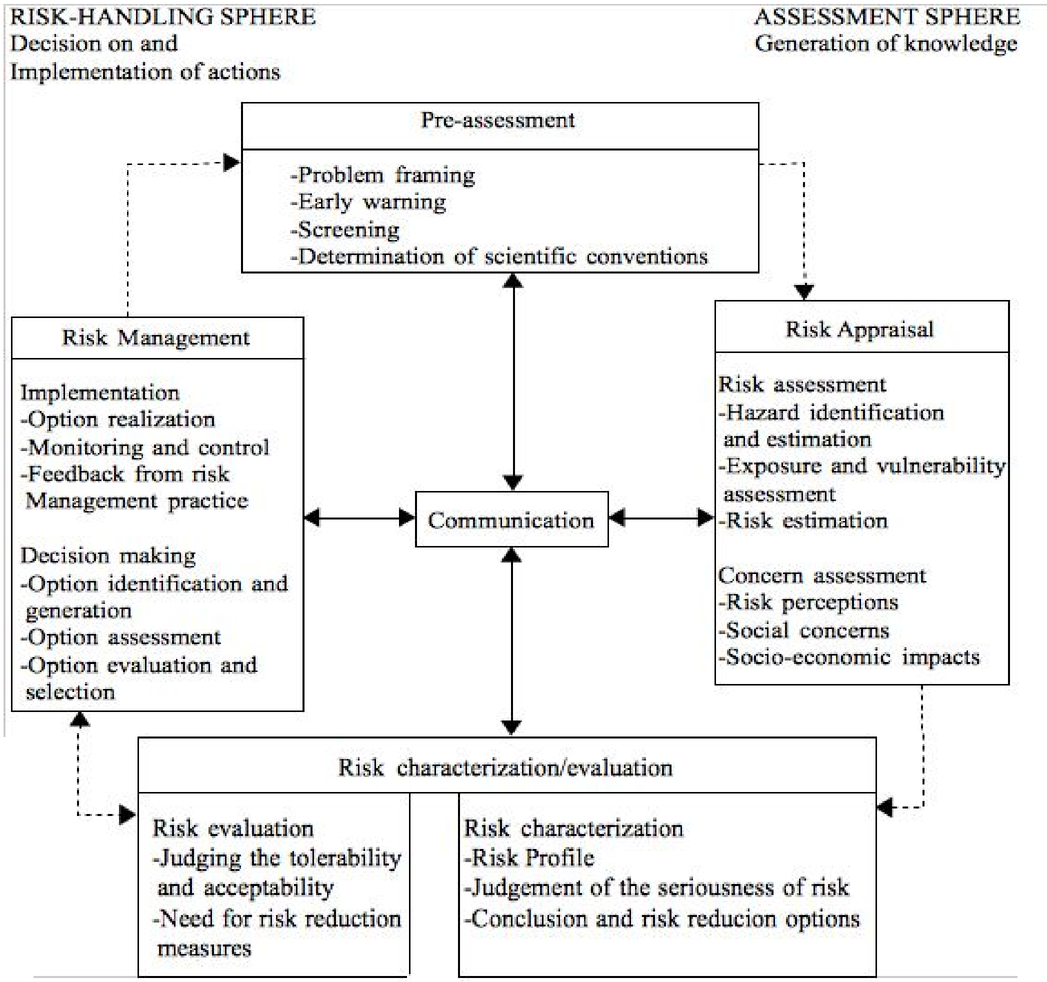

Figure 2.6.2: Basic Elements for the Risk Governance Framework
Source: Renn (2008g) pp.365.

2.7 Risk Regulation Regime

Preface

Previously in literature section 2.3 and 2.4, we have identified various risk and uncertainty (R&U) and their causal factors during one technology under development and deployment from Pearson (1991), Rosenberg (1994), Elliott (2003) and SpecialChem (2011). We also understood the principle of Renn's (2008) Risk Governance to manage R&U in a comprehensive and systematic manner. This section is aimed to understand the risk regulation regime (RRR), to examine the involvement of government and other institutions (private, semi-public) in dealing with public R&U within the socio-political setting.

2.7.1 The Introduction of Risk Regulation Regime

When decision makers/stakeholders are facing with collective/private benefits that impose R&U on public, this would create inequitable situations (Jaeger et al., 2001). The question then becomes: "What risk can a decision maker imposes on society-which includes those who do not share the benefits in full?" (MacLean, 1986; Rayner and Cantor, 1987). This is because, most of the stakeholders/policy makers are willing to impose some degree of acceptable/tolerable risks on the society, if some broader groups, or the bigger population within the society would gain the benefits. This led to some examples of infrastructure/technology installations like renewables (hydro dam construction) which puts some damaging impacts on the ecology for the sake of energy generation.

In order to balance the risk-benefit relationships, Shrader-Frechette (1984) comments, this relationship is sometimes far from being symmetrical. Therefore, the distribution of benefits and risks must be scrutinised carefully. Helps from the regulatory actions may be necessary to prevent major inequities. According to Andreeva, et al. (2009), the government's motivations are complex, but represent the wish to ensure their message is carried clearly to the public. In the context of public risk, any ruling government wishes to be seen as responding appropriately/effectively to safeguard the socioeconomic interests of the public.

The "public risk" is an anxiety which resonates a significant portion of the public. It is often closer to the public perception than to the risk related experts (Andreeva, et al., 2009), or stakeholders whom impose risks on public. Meanwhile, the "regulation of risk" is the governmental interference with market/social processes to control the potential adverse consequences. According to Hood et al. (2004a) "regime" connotes the way risk is regulated in a particular policy domain that concentrates on the public management of risks. Since many regulatory regimes involve mixture of public, private and semi-public organisations; "regime" denotes the complex of institutional geography, rules and practices associated with the regulation of a particular risk. Institutional geography can vary in features on scale, integration and specialisation [53]. Rules can vary in formality, from unwritten rules to statutory codes/targets. These rules are affecting inputs to processes, outputs for products, and penalty or incentive structures (refer appendix 2.1.2).

There are three basic features of the regime approach advocated by Hood et al. (2004a). Firstly, we see RRR as a system that consists a set of interacting/related parts rather than as single cell phenomena. It correlates the front-line people do on the ground in the activity of standard setters, and policy makers at the centre of government. Secondly, RRR is an entity that has some degree of continuity over time, and does not appear as completely static. This complies with the nature of politics-which is dynamic/evolving over time and there are always debates about the direction politics on its development. The RRR has its sudden climacterics, as well as incremental adjustments and steady trends. It is dynamic/evolving, either due to a minor adjustment into an existing regime, or an extra item/new inputs to be added to the routine will cause a step-change in the regime. Thirdly, regimes are conceived relatively bounded systems that can be specified at different levels of breadth. While regimes could be described from an overall system, we can also conceive the regime

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53 Scale: from international level, national level to local jurisdiction.
Integration: from a single agency handling all features of regulation, to highly fragmented administration and complex overlapping systems controlling related aspects of a risk event.
Specialisation: from a risk-specific and hazard-specific expertise to a general-purpose administration.
Source: Hood et al., (2004a).

in a narrower sense as the system of control that centres at different levels[54]. Hence, we have to specify what level (basic, middle or the highest prioritised level) of regime is being analysed (Hood et al., 2004a).

2.7.2 The Anatomy of Risk Regulation Regime

Hood et al. (2004b) explains, the anatomy of RRR begins with two dimensions. Firstly, a dimension has three components that forming the basis of a control system. It includes:

(a) ways of gathering information to produce knowledge about current/changing states of the system;

(b) ways of setting standards, goals, and targets; and

(c) ways of changing behaviour to meet the standards/targets.

Next, the second dimension is to investigate the "context" and "content" (will be explained in 2.7.2.2).

2.7.2.1 Three Control Components of Risk Regulatory Regime

(a) Information Gathering (IG)

Information about risks could be gathered with numerous ways: regulators conducting their analyses; by imposing legal requirements to report/test/register by others; by paying others to provide information; or it can be provided voluntarily by complainants, whistle-blowers/individuals who are willing to contribute. Risk regulators also vary in the extent to which they gather information by active[55], reactive[56], or interactive[57] methods (Hood et al., 2004b).

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54 For example, if taking the risks to patients associated with health care, we could conceive the regime for controlling those risks as composed of all the regulatory activities that affect health care directly/indirectly. Those activities (at a higher level) include attempts to control the risk from dangerous doctors/other health-care workers, by attempts to exclude unqualified medical workers from practice. Then, to control the risk (at a middle level) from dangerous drugs/medical equipment by drugs approval procedures testing for side-effects and efficacy. Furthermore, to control the risk (at a basic level) from dangerous of infectious diseases by controls strictest international medical procedures, banned contaminated blood and prioritise the cleanliness of the environment (Hood, et al., 2004a).

55 It is known as police patrol in the oversight-systems, means regulators scan the environment, seeking out and assembling information about the policy issue in question (Hood et al., 2004b).

56 It is known as fire alarms, means regulators rely on others to come forward with information (Hood et al., 2004b).

(b) Standard Setting (SS)

The standard setting comprises goals/targets/guidelines and measurements. Standards could be emerged from a technocratic process that applies technical approaches and draws on systematic tests. Standards sometimes emerge from bargaining among stakeholders with different interests, producing solutions represent a compromise between rival positions or the interests of different parties (Hood et al., 2004b).

(c) Behaviour Modification (BM)

Changing individual/organisational behaviour is challenging. One of the debates over BM in the law and regulation literature, concerns the relative merits of compliance[58] and deterrence[59], as ways of applying legal/regulatory standards (Hawkins and Thomas 1984). However, some regulatory designers such as Ayres and Braithwaite (1992) argue for a hybrid approach by mixing them both. This advocates the compliance responses towards regulatees who are identified as poorly informed or morally concern about the regulatory requirements. Meanwhile deterrence approaches is for those regulatees who demonstrate themselves to be opportunistic or amoral.

2.7.2.2 The Context and Content of Regimes

As shown in table 2.7.1, the "three control component of RRR" (discussed at 2.7.2.1) are varied in the context[60] and content[61] (refer appendix 2.7.1). According to Hood et al. (2004b), the six elements of regime context and content cover a wide range of ways in which regulatory regimes can work (refer appendix 2.7.2).

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57 It comes somewhere in between the active and reactive, typically through regulators imposing periodic reporting requirements on others and then responding to the content of the reports (Hood et al., 2004b).
58 The compliance doctrines rely on diplomacy, persuasion and education, rather than routine application of sanctions to produce a compliance culture on the part of those affected by regulation (Hawkins and Thomas 1984).
59 The deterrence doctrines rely on the credibility of penalties/punishment, expressed in the expected cost of non-compliance to violators, to prevent those regulated from breaking the rules (Hawkins and Thomas 1984).
60 The regime context means the setting in which regulation takes place (Hood et al., 2004b).
61 The regime content means the regulatory objectives, the configuration of state and other organisational structure directly engaged in regulating the risk (Hood et al., 2004b).

Table 2.7.1: Elements of Context and Content

	Control Components		
Context (a) Type of risk (b) Public preferences and attitudes (c) Organised interests	Information gathering	Standard setting	Behaviour modification
	Control Components		
Content (d) Size (e) Structure (f) Style	Information gathering	Standard setting	Behaviour modification

Source: Hood, et al., 2004b. pp.29.

2.7.3 Involvement of Government in Risk Regulation Regime

There are three hypotheses-according to Hood et al. (2004c) that seek to explain why the government involve with risk regulation.

(a) Market Failure (MF)

MF hypothesis is based on the assumption that the government will not interfere the markets' self-regulation, unless there is a danger of failure (Breyer, 1982; Ogus, 1994). The level of possible interference is determined by information cost[62] and opt-out cost[63] of a particular hazard. It is expected that government will interfere when either of these costs is substantial (Hood et al., 2004c).

(b) Opinion Responsiveness (OR)

This is a populist approach, which the government follows public opinion/preferences-the stronger the opinion, the stronger the response (Breyer, 1993). However, the OR hypothesis offers an incomplete explanation. This is because: Firstly, it is difficult to measure a public's opinion to form a representative picture. Although polling is a preferred method, it is not without limitations (Dryzek, 1990; Fishkin, 1995). Secondly, even though the alternative methods (focus groups) were used; Hood et al. (2004c) argue, the opinion was limited and selective. Thirdly,

62 relates to the cost of assessing the level, impact of danger the people are exposed to (Hood et al., 2004c).
63 relates to the cost of avoidance/mitigation of a particular hazard (Hood et al., 2004c).

public opinion is volatile and distorted by media (Hood et al., 2004c).

Alternatively, the government could rely on the "experts" to get information about public opinion. There are two-forms of experts: Firstly, those who are employed by the government [64] and secondly, the perceived experts [65] from the issue lobbyists (Andreeva, et al., 2009). Both types of expert may raise issues that are picked up by others, or from the media. Their motivation may be laudable for self-publicity or intention for social justice. If their view fits in within a political agenda, then government may find they are helpful. If they are on the opposite side of the regulator and become the focus of other groups/media, it will turn to be hard for government to ignore them.

(c) Interest Pressures (IP)

Political science and political economy theories argue that, the government's response to risk is mainly driven by interest groups' pressures-best investigated is about business lobbyists (Self, 1985; Wilson, 1990). Yet, there are other pressure groups, such as labour unions, consumer organisations and environmentalists.

Literature on business lobbying goes back to the Chicago school. It explains that business firms would organise themselves into groups, aiming at influencing/shaping regulations to protect/enhance their profits (Stigler 1971, Peltzman 1976). Hood et al. (2004c) refer to the these pressure groups as "policy entrepreneurs" which often have their own agendas, apart from defending the public interests, or protecting community which they represent. Hood et al. (2004c) admit, it is difficult to separate group interests from public opinion, and it is common for regulators to see the pressures coming from such groups as the expressions of public opinions (refer appendix 2.7.3[66])

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64 They provide the government (through employment relationship) with advice which is based on their own skills and knowledge (Andreeva, et al., 2009).

65 They are perceived as having credibility through their qualifications, position/representation in one society, the research they can quote, or even the attention they receive from others (Andreeva, et al., 2009).

66 The appendix discusses the example of the GM product (advocated by Fischer, 2004), which

2.7.4 Triggers and Time Elements of Public Risk

Generally, experts often have lower estimates of risk than both the government and the public. Mostly, it is the scientific advice given to a government that will shape a government policy rather than public opinion[67]. To understand political interaction with public risk, it is sensible to consider how public risk may be triggered, with some elements are described as "events", "innovation" and "change"[68]. However, time plays a central role in public risk and reaction towards it. Time often determines the action taken by government and subsequent reaction by the public. If government is perceived not to take action within a reasonable time, the public's concern may be heightened. A sense of crisis could be developed that takes on its own momentum, and risk supersedes to become the focus of the public. This can have some very negative consequences for government. Even though governments hope that their action could allay public anxiety, in some contexts this is not the case. Furthermore, campaigns and the media in reality and in certain degree do affect public attitudes and amplify the public anxiety (refer appendix 2.7.4).

2.7.5 Precautionary Principles in Policy Formulation

For public activities that administrated by a government (like new technology introduction), a clear set of benefits could be anticipated by those who are supporting the activities. However, the risks associated with these activities arise when things do not go as planned. This is often the case when risks arise from processes within a complex system, involving ecology and sociocultural institutions. The complexity of these effects can make it very difficult to assess and reduce the resulting uncertainty. Such concerns are part of the motivation for precautionary approaches that would

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illustrates the different opinions between various groups/institutions.

67 In a study of government and the public risk perceptions in Sweden, Sjoberg and Drottz-Sjoberg (2008) found that, government and the public have similar risk perceptions across a range of risks studied, except for nuclear waste, where the public perceived a greater risk than government. In nuclear waste policy, the government study tends to base on their policy attitudes, as well as on their own risk perceptions, but not the views that they believed the public has. The reason may be that government perceives benefits arise from nuclear power which the public do not accept.

68 Events often trigger public concern, such as the outbreak of Foot and Mouth Disease, sinking of the Herald of Free Enterprise, the train accident at Ladbrook Grove etc. Innovation on technology, can also lead to public concern, for example GM foods and the sitting of nuclear plants. Changes in contexts can also cause risk, such as changes in banking practices were contributing factors to credit crunch (Andreeva, et al., 2009).

substitute highly protective decisions/rules, for the calculations and trade-offs on risk-based decision-making (Dekay, et al., 2009).

Page (1978) offers a characterisation of the types of risk, which support for precautionary approaches is the most likely to arise:
(a) there is an ignorance of mechanism, so that our knowledge of the physical processes that determine the likelihood and magnitude of the risk is poor;
(b) there is a potential for catastrophic loss, so that the harm to the affected individuals and society can be great if the activity/technology entails such a risk;
(c) there is a relatively modest benefit associated with the activity/technology, especially when compared to the potential harm; and
(d) there is a low subjective probability associated with the feared outcome.
However, there is often no consensus about the probability of occurrence, due to the rarity/one-of-a-kind nature of the risk, with little/no actuarial history upon which to base estimates.

Page (1978) argues that, traditional regulatory approaches are inadequate for problems listed above. These approaches have often focused solely/primarily on limiting false positives-by assuming that new technologies are safe and beneficial until proven otherwise. Furthermore, conventional policies have often failed to address the implications of differences in the distribution of benefits-and-costs; especially when those exposed to the greatest risk do not receive a commensurate portion of the benefits. Some risks are latent, not exhibited until far into the future, making it difficult and sometimes impossible to prevent future damages/losses.

As a result, precautionary approaches for dealing with risks have been proposed to embody in various forms of the precautionary principle (Raffensperger and Tickner, 1999; Commission of the European Communities, 2000). The principle is designed to ensure the intentions to protect political stability, safeguarding social, economical and environmental harmonisation. The Commission of the European Communities (2000) has attempted to refine the precautionary principle, stating that it should be considered within a structured risk-analysis approach that incorporates information regarding the economic and non-economic benefits, and also costs of the various policy options. Such assessments can consider the multiple political, environmental, economical and social impacts that occur over time. Possible outcome are characterised by weighting and combining various impacts into a series of parameters and weighting them by their probabilities to generate an expected values for each decision alternative (Raiffa, 1968; Keeney, 1982; Clemen, 1996). Then this is designed to clarify trade-offs among different concerns for individual decision maker, or multiple stakeholders who share a common view of a decision. This is not to say that different parties must be agreed on the appropriate course of actions. However, full rational considerations may show that a decision that appears have the appropriate amount of prudent precaution for its proponents (Dekay, et al., 2009).

2.7.6 Conclusion

Hood et al. (2004a) concentrate on the public management of risks, but do not solely focus on the state involvement in a narrow sense. This is because the RRR involves a mixture of public-private and semi-public organisations. Hence, RRR denotes the complexity of institutional, geography, rules, practices and ideas, associated with the regulation of a risk event. The institutional and geography can be varied in scale, from an international to a national setting. In the real practice, there is no single agency (public, private, or semi public institutions) which should be assigned solely to handle all R&U. The wide focus of RRR, matched well to the researcher's topic, involving both the government and the oil companies who have been taking up biofuels adoption, while dealing with R&U arise during biofuels deployment and development.

There are three basic features of the RRR approach: interpreted as systems, continuity and regimes. These basic features of regime constructed a fundamental context for risk analysis. The interpretation of regime as a system helps the researcher to investigate the mechanism applied within the system (road transport system); such as instruments, strategies and methodologies adopted for biofuels deployment and development. Besides, the continuity of the regime signify the context that could have the capability of accommodating any further innovations, changes (increasing/decreasing affords), improvements, modifications as well as the results of termination. Furthermore, the regimes which could be specified at different levels of analysis enable the researcher to focus entirely at the UK, yet relate its correlations with the EU, and regional/international government bodies which are shaping the biofuels deployment and development.

Three components (IG, SS and BM) are the mechanism utilised by the government to have the R&U managed. They formed an interconnected controlling system to drive both biofuels development and deployment in meeting the objectives of nationwide biofuels application. Besides, Dekay et al. (2009) and Page (1978) advocate the precautionary principle required in policy formulation, to ensure the intentions to protect political stability, safeguarding socioeconomical and environmental harmonisation.

Meanwhile, the anatomy of the context and content of a regime provide a clear distinction in explaining the regime of biofuels development and deployment in the UK. Under the regime hierarchical structure, the UK government commences biofuels nationwide has a strong correlation with the EU Biofuels Directive (2003). The Scottish Government (SG) is also deploying biofuels in Scotland, due to the context and the style of power delegation between Scotland and the UK. Both have the identical regulatory contexts, risk contexts, institutional interests and policy contents in biofuels development and deployment under the UK Renewable Transport Fuel Obligation (RTFO). Therefore, we can observe a “conjoint” RRR, the massive size extending from the EU to the UK, in order to suit the issue of localisation. Finally, three hypotheses from Hood et al. (2004c) on MF, OR, IP (refer 2.7.3); seek to explain why the government involve with risk regulation would be used to guide the researcher's biofuels case study.

Chapter 3 Research Methodology

Preface

The research methodology maps out the methods that a researcher has utilised whilst conducting his/her research. Driven by the research questions and objectives, this chapter provides a thoroughly description of the grounded theory/philosophy; explaining how data collection was conducted, while justifies the analytical procedure used which led to a sound conclusion made. This chapter begins with a discussion of the research philosophy (section 3.2), the research methodology (section 3.3), the research design (section 3.4), the questionnaire design (section 3.5), reflexivity (section 3.6 and 3.7), the analytical procedure (section 3.8), and finally the validity, reliability and generalisability (section 3.9).

3.1 Introduction

The research epistemology was grounded on the social constructivism, whilst the research design was established through a purpose-based (exploration) choice of study. The areas of the study were explored, then supported by cases studied (the Scottish Government, BP (UK) PLC and Shell (UK) PLC) conducted through interviews, observations and documents analysis in qualitative method. Thus, the aim of this chapter is to demonstrate the researcher understood the theories, and to lay out the methodological considerations used to answer the research questions, and to achieve the research objectives initially set.

3.2 Research Philosophy

Zalan and Lewis (2004) state, ontology asks about reality. It asks whether "reality", is in fact objective[69], or whether it is the internal creation of an individual cognition/intellect, which cannot exist on its own. The central question of ontological concerns "What do we believe about the nature of reality" since it stresses on the "nature of being" (Patton, 2002; Denzin and Lincoln, 2003).

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69 means external to an individual and existing independently. It depends on how people see/judge it (Zalan and Lewis, 2004).

On the other hand, epistemology is the philosophical theory of knowledge. It concerns with the external validity, generalisability, explanation and causality (Zalan and Lewis, 2004). Some of the main questions of epistemological debate are “How do we know what we know?” (Patton, 2002); and “What is the relationship between the inquirer and the known?” (Denzin and Lincoln, 2003) (refer table 3.1). According to Easterby-Smith et al. (2004), social scientist is looking at these three ontological positions: representationalism[70], relativism[71] and nominalism[72]. The acceptance of a particular epistemology will lead a researcher to opt for a method that is characterised by that ontological position. Table 3.2 summarises the correspondence between the three epistemologies and methods in social science study (Easterby-Smith et al., 2004).

Table 3.1: Ontology and Epistemology in Social Science

Ontology of Social Science	Representationalism	Relativism (refer appendix 3.2.1)	Nominalism
Truth	Determined through the verification of predictions	Requires consensus between different viewpoints	Depends on who establishes it
Facts	are concrete, but cannot be accessed directly	depend on viewpoint of observer	are all human creations
Epistemology of social science	Positivism (refer appendix 3.2.2)	Relativism (refer appendix 3.2.3)	Social Constructivism

Source: Easterby-Smith, et al. 2004. pp.33.

70 Representationalism: whether or not phenomena are concrete. It is only possible to gather indirect evidence of what is going on in fundamental physical processes (Putnam, 1975). Hence, representationalist asks whether the research results are an accurate reflection of reality. This is because, representationalist believes that reality could be observed and measured.
71 Relativist: assumes that, different observers may have different viewpoints. What counts for truth could be varied from one place to another, as well as from time to time. Thus, the relativist would want to ensure that a broad sample of viewpoints has been taken into account (Collins, 1983).
72 Nominalist: includes the view that, it is the labels and names that we attach to experiences and events which are crucial. The nominalist is interested where the labels came from and who influenced their acceptance (Easterby-Smith et al., 2004).

Table 3.2 Methodological Implications of Different Epistemologies within Social Science Study

Elements of Methods	Positivism	Relativism	Social Constructionism
Aims	Discovery	Exposure	Invention
Starting points	Hypotheses	Suppositions	Meanings
Designs	Experiment	Triangulation	Reflexivity
Techniques	Measurement	Survey	Conversation
Analysis/interpretation	Verification/falsification	Probability	Sense-making
Outcomes	Causality	Correlation	Understanding

Source: Easterby-Smith, et al. 2004. pp.34.

These three philosophical positions are the pure/confined versions of each paradigm. According to Easterby-Smith et al. (2004), although the basic beliefs may be quite incompatible, when one comes down to the actual research methods, the differences are by no means as clear and distinct. Moreover, some management researchers deliberately use methods which originate in different paradigms.

3.2.1 Social Constructivism

Social constructivism focuses on the ways that people make sense of the world. Through experience/knowledge sharing via the medium of language, information is diffused (Berger and Luckman 1966; Watzlawick 1984; Shortter 1993). There are two key ideas of social constructivism. Firstly, the "reality" is not objective and exterior; rather it is socially constructed and given meaning by people. The constructionist perspective starts from a viewpoint which does not assume any pre-existing reality. The aim of a researcher is to understand how people invent structures, in order to help them make sense of what is going on around them. Consequently, much attention is given to the use of language through conversation between people. Given a observer/researcher can never be separated from the sense-making process; this means a researcher/observer is starting to recognise, that theories which apply to the subjects of his/her work must also be relevant to him/herself (Easterby-Smith et al., 2004).

Secondly, one should try to understand and explain why people have different experiences, rather than search for external causes and fundamental laws to explain their behaviour. Human action arises from the sense that people make of different situations, rather than as a direct response to external stimuli. Hence, the task of the social scientist/researcher should not to gather facts and measure how often certain patterns occur, instead to appreciate the different constructions and meanings that people place upon their experience. The focus should be on what people, individually/collectively is/are thinking. Attention should be paid to the ways they interact with each other (Easterby-Smith et al., 2004). The methods of social constructionist research could be contrasted with the eight features summarised in Table 3.3.

Table 3.3: Social Constructivism and Its Eight Features

Features	Social Constructivism
The observer	is part of what is being observed
Human interests	are the main drivers of science
Explanations	aim to increase general understanding of the situation
Research progresses through	gathering rich data from which ideas are induced
Concepts	should incorporate stakeholder perspectives
Units of analysis	may include the complexity of whole situations
Generalisation through	theoretical abstraction
Sampling requires	small numbers of cases chosen for specific reasons

Source: Easterby-Smith, et al. 2004. pp.30.

This study opted for the social constructivism which aimed to understand a technological change that incurred expected/unexpected risk and uncertainty (R&U). By using the theories of Social Shaping Technology, Risk Governance and Risk Regulated Regime; the application of Social Shaping Technology was aimed at broadening the Risk Governance and Risk Regulated Regime, and assisted the researcher to look at R&U of a technological change from a social dimension.

The subject of the study involved the Scottish Government (SG) and two oil companies-BP and Shell as cases studied. Through experience sharing and resources combined, these stakeholders have implemented strategies to deal with the different types of R&U that emerged during biofuels deployment and development. The strategies were intended to ease the commencement of the 1G biofuels, and to materialise the next generation biofuels (NGB) development.

The dynamism of the sociotechnological change is explained by Sztompka (1991). The adoption/innovation of a technology within a social reality is never a steady state, rather a dynamic process. This is because, the social process and technological change are created by human agents. Through individual/collective decisions made, interactions are generated. As such, social constructionism suits this type of research. Easterby-Smith, et al., (2004) further support that, the strength of the social constructionism and qualitative methods are complementing one another since both have the ability to bring-out and make-sense on people's meanings.

3.3 Research Methodology

The choice of methodology is determined, not only by the ontological and epistemological stance of the researcher, but is also influenced by the objectives of the research. Taylor and Bogdan (1998) state, methodology refers to the way[73] a researcher approaches the problems and seeks answers. Besides, Fisher (2004) describes methodology as the study of methods. It raises all sorts of philosophical questions: for example "What is possible for researchers to know?" "How to validate a researcher claims to knowledge?"-which Leedy (1989) then describes as an operational framework where the facts are placed, so that their meaning may be seen more clearly.

Additionally, Ghauri et al. (1995) claim that research methodology can be conceived as a system of rules and procedures-which are important for several reasons:
(a) it can be conceived as rules for reasoning, a specific logic to acquire insights of a study.
(b) it is important for inter-subjectivity. Reporting (in detail) how a researcher has obtained his/her findings, means that his/her work can be evaluated by others,
(c) it can also be considered as rules for communication. Reporting on the rules and

73 The term applies to how the research is conducted, what the assumptions are, and what are the interests/purposes a researcher has which shapes the methodology chosen (Taylor and Bogdan, 1998).

procedures used, enables others try to replicate/criticise the approach chosen.

Thus, qualifying research requires a competence in logical reasoning and analysis. A researcher therefore needs to have command over the research methodology used. Research, however, is also closely related to finding, structuring and solving problems to answer problems/questions-since problems represent the point of departure in one study. In order to grasp the comprehension of problems, an understanding of the concepts/theories surrounding the problems is crucial. Furthermore, the ability to think conceptually is important as a prerequisite for doing qualifying research (Ghauri et al., 1995).

3.3.1 Qualitative Research

Research methods refer to the systematic, focused and orderly collection of data; for the purpose of obtaining information to solve/answer the research problems/questions (Ghauri et al., 1995). Thus, which method (qualitative or quantitative) is most suitable for a research project, depends on the research problem and the objective of the study (Jankowicz, 1991). In qualitative research, findings are not arrived by statistical methods/procedures of quantification. It is a mixture of the rational and explorative, where the skills[74] and experience of a researcher play an important role in the analysis of data (Ghauri et al., 1995).

Supported by Denzin and Lincoln's (2003), qualitative research cuts across disciplines, fields[75] and subject matters[76], all of which are complex and have interconnected terms, concepts and theories surrounding the research. As such, the qualitative method is the practical purpose in the ways of finding out what people

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74 Skills needed for a qualitative research: thinking abstractly; stepping back and critically analysing situations; recognising and avoiding biases; obtaining valid and reliable information; having theoretical and social sensitivity; and the ability to keep analytical distance while at the same time utilising past experience, with a shrewd sense of observation and interaction (van Maanen, 1983; Strauss and Corbin, 1990).

75 Social Shaping Technology, Risk Governance, Risk Regulated Regime.

76 Technological change, renewable energy for transport, biofuels, R&U during biofuels deployment and development, corporate strategies, government administration through policy formulation and introduction.

do/know/think/feel; by observing, interviewing and analysing (Patton, 2002) to understand people from their own frames of reference (Taylor and Bogdan, 1998). Driven by the research objectives (refer section 1.2), the qualitative method (that adopted interview, observations and document analysis) were chosen to conduct this study. The emphasis of qualitative method is illustrated in Table 3.4.

Table 3.4: Emphasis in the Qualitative Method

Emphasis on understanding
Focus on understanding from respondent/informant point of view
Interpretation and rational approach
Observations and measurements in natural settings Subjective “insider view” and closeness to data
Explorative orientation
Process oriented[77]
Holistic perspective[78]
Generalisation by comparison of properties and contexts of individual organism

Source: Reichardt and Cook. 1979.

3.3.2 Type and Purpose of Research: Exploratory Study

Omerod (1996) states that there are five types of research under the qualitative method (refer appendix 3.3.1); while this research was an exploratory study, which could be justified by two reasons. Firstly, exploration is useful when a researcher lacks a clear idea of the problems he/she will meet during the study (Cooper and Schindler, 2008). The technological change has incurred various R&U during biofuels deployment and development. This shows that biofuels introduction and innovation are complex and highly uncertain. Thus, effective strategies from the regulators and oil companies operating within the biofuels regulated market have to be effectuated to resolve/mitigate R&U incurred, in order to ensure biofuels execution/development could achieve the ultimate objectives set. Yet, in reality, the researcher lacked a clear idea about what R&U would be faced, and what strategies

77 A social process is difficult to study with quantitative methods. Hence, qualitative method is the most suitable and can provide intricate details and understanding (Ghauri et al., 1995).
78 Whenever a holistic, dynamic and contextual explanation of the phenomenon is required (like technological change for biofuels deployment and development), qualitative method would be the most appropriate choice (Zalan and Lewis, 2004).

would be adopted to resolve/mitigate them accordingly. This information could only be obtained through field work.

Secondly, the area of investigation is new/green-field. Hence, the researcher needs to explore/develop some concepts to establish priorities and operational definitions (Cooper and Schindler, 2008). Although the research design had been established in the second year of the study; yet, it has a certain degree of flexibility in nature in order to accommodate new inputs[79] along the research execution process. Since the technological change is a dynamic process which keeps evolving, the researcher has to continuously engage in searching, updating and reviewing the latest information (secondary data), and to obtain (primary data) through interviews and observations on cases studied.

3.3.3 Research Strategy: Case Study

Yin (2003) defines research strategies as ways of investigating an empirical topic, by following a set of pre-specified procedures. Furthermore, Denzin and Lincoln (2003) suggest, there are several research strategies that are commonly used in a research[80].

For this study, the case study strategy was adopted. Case study is a way of establishing valid/reliable evidence for the research, as well as presenting findings resulted from the research (Remenyi et al, 1998). It focuses on a single organisation/institution/group, which serves as the case being studied (Baker, 1999). The primary advantage of case study is that, an entire organisation/entity could be investigated in depth and with meticulous attentions to detail. This highly focused attention enables a researcher to carefully study the order of events as they occur, or to concentrate on identifying the relationship among functions/individuals/entities (Zikmund, 2003).

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79 For example, until which stage the biofuels implementation/innovation processes should be investigated; are largely depend upon the proliferation of the international/regional/nation political decisions, as well as the advancement of biotechnology in the NGB development.

80 [1]Study design; [2]Case study; [3]Ethnography (participant observation, performance ethnography), [4]Phenomenology; [5]Grounded theory; [6]Life history; [7]Historical method; [8]Action and applied research; [9]Clinical research.

Yin (1994) states that, a case study could be defined as an empirical inquiry that investigates a contemporary phenomenon within its real life context. It may be largely exploratory/descriptive, since it examines current phenomenon in a real life situation, with multiple sources of evidence being used. A case study strategy is particularly valuable in answering research questions of “why” and “how”, which often seeks explanations. Besides, Bell (1993) adds, the philosophy behind a case study is that: sometimes, by looking carefully at a practical and real life instance, a full picture could be obtained from the actual interaction of variables/events. It is the aim of the case study to provide a multi-dimensional picture of the situation. Thus, Remenyi et al, (1998) agree, a case study strategy allows a researcher to concentrate on the specific instances, in an attempt to identify detailed interactive processes.

The exploratory study was chosen, because it helped the researcher to develop clear concepts along the research progresses. Likewise, the research strategy which employed case study could provide insight of research phenomena on the technological change. Hence, this has suggested qualitative research (more plausible than quantitative) since the qualitative is capable in interpreting meaning, making sense of data and producing new ideas/concepts towards theory building.

3.4 Research Design

Cooper and Schindler (2003) and Ghauri et al. (1995) describe, research design is the strategy for a study, and the plan to collect the information needed. There are three essentials of a research design:

(a) It is a plan for selecting the sources/types of information used to answer the research question.

(b) It is a framework for specifying the relationships amongst the study’s variables.

(c) It is a blueprint that outlines each procedure, from the hypotheses to the analysis of data.

Thus, Yin (2003) emphasises, a research design is the logic that links the data to be collected to the initial research question.

Ghauri et al. (1995) specify, there are six activities[81] which are guide the research process. Yet, these activities are not rigidly sequential as expected. Since the exploratory study has been applied, emerging inputs/latest updates have to be captured from time to time. Often, when a researcher is working within an exploratory research, the initial problem set may need to be reframed from time to time. This is because, new insights may emerge, which influence the understanding of the problem. Thus, research activities have to be constantly evaluated. The following sections explain further on research question formulation, literature selection, data collection and data analysis.

3.4.1 Building the Analytical Framework through Literature Review

Rose and Sullivan (1996) explain, social science research is concerned to explain the society exhibits. When we consider "How a social researcher explains?", "Where his/her explanations begin from?"-the answer is from theory. Theory is a form of selective focusing-a way of separating out from the confusing world, which assails our senses with the elements of reality that concern us as a social researcher. In doing any research, we have questions we wish to answer. However, those questions must always derive from theory. Thus, research is a theory-guided process that leads in the end to a new way of thinking about the world.

Therefore, we need to have a theory before we can observe anything about the social world. The theory must be capable of being operationalised in a way which enables facts to be measured (Comte, 1853). Aligned with this, Zikmund (2003) affirms, theories allow us to select from a mass of confusing materials, in order to form a coherent set of general propositions that can be used to explain the apparent relationships among certain observed phenomena. Thus, literature review is the process of searching relevant theories, to build up the concept/content/context of the

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81 [1]Problem definition, [2]Research design, [3]Measurements, [4]Data Strategies, [5]Data Analysis, [6]Research Report. A distinction may be drawn at activity 1 (problem definition), which may be classified at the conceptual/theoretical level. Meanwhile activities related to steps 2-5 are at the empirical level. Finally, activity 6 is aimed to communicate/disseminate the produced findings (Ghauri et al., 1995).

research.

According to Ghauri et al. (1995), the prime purposes of literature review are:

(a) to frame and structure the research problem;

(b) to identify relevant concepts, methods/techniques and facts;

(c) to position the study, while adding something new.

Besides, literature review is defined as the process of describing and criticising relevant literature within a particular subject area.

In order to make sense of the literature, and to find out the literature pertinent to Social Shaping Technology, Risk Governance and Risk Regulated Regime, the researcher started the literature search by identifying who are the gurus within these fields, and then searched for their published works. According to Drucker et al. (1990), good gurus possess timing and the intuitive ability to fasten on and to articulate trends before others see them. With in-depth knowledge of their special areas, they can situate within a wider context of evolving social trends. Consistent with this, the gurus are those who could change the paradigm, as they change the way people look out from the window of the world.

Within the field of Social Shaping Technology, the gurus have been identified and universally agreed are: (a) Donald Mackenzie (b) Judy Wajcman (c) Robin Williams (d) David Edge, while some of the recognised international scholars in this field are (a) Knut H. Sørensen (b) Arie Rip (c) Johan W. Schot (d) Steward Russell (e) Shen XiaoBai (f) Matthias K. Weber. Meanwhile in the field of Risk/Risk Management, the universally recognised are: (a) Ulrich Beck (b) Ortwin Renn (c) Christopher Hood (d) Roger E. Kasperson and Jeanne X. Kasperson (e) Jake Ansell. Furthermore, to correlate the subject of the study in renewable energy from social science angle, the guru is: (a) David Elliott; while contributors in managing R&U from corporate strategies are: (a) Nathan Rosenberg, and (b) D. M. Pearson.

By identifying the leading gurus/scholars in these fields made it possible for the researcher to go through their works-which are mainly appeared in the form of books, chapters of books, journal articles and online database journals[82] (refer appendix 3.4.1). Furthermore, the researcher has also conducted the literature search using the proceedings, articles and publications from some of the reputable organisations[83]. Therefore, literature review enabled the researcher to draw on research ideas, refine the research concepts and to set up analytical frameworks to validate them via cases studied.

Through the focus on theories of Social Shaping Technology, Risk Governance and Risk Regulated Regime, the researcher has built a grounded concept, content and context for technological change which incurred R&U; involving large social technology (biofuels) deployment and development. Simultaneously, the researcher has also searched, analysed and synthesised the secondary data including tracking the international/regional/national policies, corporate reports, international/national media materials[84] and website publications from the related organisations[85]. From the theoretical concept to the secondary data, the applications of these theories were testified (as advised/guided by the researcher's supervisors), while the actual scenarios in technological change are comprehended. This helped the researcher to identify gaps and under-researched areas, which led to research questions formulated and research objectives established.

3.4.2 Data Collection Methods

Under a qualitative method with case study strategy, there were three approaches adopted for this research: interview, observation and document analysis.

(a) Interview

An interview is a conversation with purpose, to yield direct quotations from people

82 such as: Emerald, Science Direct, Jstor, Sage and others.
83 [1]Publications from the European Association for the Study of Science and Technology; [2]Publications from the Society for Social Studies of Science (4S).
84 The broadcasting media such as BBC, and the print media like the Guardian, the Independent, the Scotsman, the Telegraph and others.
85 The UN/EU/UK/Scottish Government and their related agencies; BP and Shell, and other social movement/learned societies and environmentalists.

about their experiences, opinions and knowledge. Data consists of verbatim quotations with the sufficient context to be interpretable (Cooper and Schindler, 2008). Along the interview process, the researcher utilised the questionnaire (refer appendix 3.4.2a and 3.4.2b) as the primary data collection tool to gather the respondents' responses.

Zikmund (2003) advises, by conducting an interview means to establish a discussion with the well-informed respondent. This could lead to an understanding of a complex situation. Although the researcher has been equipped with the secondary data found, the aim for an interview was to gain the justifications to answer the questions of "how" and "why", which usually could not be explained by the secondary data gathered. Besides, taking into a consideration the researcher's background[86]; some of these needed to be explained by the respondents through an interview.

However, Zikmund (2003) reminds us that a researcher who applies this method must be flexible and attempt to glean information and insights. The freedom to search for data a researcher deems necessary makes the success of any case study highly dependent on the alertness, creativity, intelligence and motivation. The researcher has some experience of interviewing corporate executives and public agency representatives at home. There are few issues which have to be considered when interviewing the designated respondents-particularly at effective time management and be efficient throughout the interview process (refer appendix 3.4.3).

Since the researcher has decided for an in-depth case study, Easterby-Smith et al. (2008) remind us for an in-depth case study: Firstly, it is based on personal contacts, generally through interview. Secondly, it takes place within a single organisation, but then involves the selection from a number of individuals, which were mainly based on their designations/job descriptions that relevant to the research topic. Thirdly, the collection of data takes place over a period of time, and may include both live

86with a limited knowledge of the local circumstances, the UK governing system and the regulated market.

observations and retrospective accounts of what has happened.

(b) Observations

This is a fieldwork description of activities, behaviours, actions, conversations, organisational or community processes; or any other aspect of observable human experience. Data consisting of field notes are rich with detailed descriptions, including the context within which the observations are made (Patton, 2002).

The researcher used the method of streaming media (of organisational websites, independent news agencies from international/national broadcasting/print media), with the focus on a conceptual/thematic analysis as “hands-on observation” to capture the relevant issues surrounding the research concept. This is supported by Wilkinson and Birmingham (2003), where the conceptual/thematic analysis is one of the methods under content analysis. It examines either the incidence or the frequency of concepts, such as themes/issues/words/phrases that appear in a text. The key focus is on the themes/issues within the text that the researcher intends to observe and analyse.

Apart from streaming media, field observation has also been carried out. The researcher has captured the on-going works executed by respective stakeholders: the SG, BP and Shell, together with other relevant actors such as the UN/EU/UK Governments, international/national broadcasting/print media, international/national social movements, learned societies and environmentalists. Firstly, the interactions between stakeholders were observed. Secondly, how the expected R&U occurred, as well as the emergence of systemic risks-which caused public anxiety were captured. Next, how the media and pressure groups amplified the systemic risks and put pressure on regulators/oil companies were observed. Then, how the regulators/oil companies strategised themselves to counteract with expected/unexpected R&U, as well as their response to the pressure coerced by international/national media, social movements and environmentalist were noted. Furthermore, how the NGB technology has been shaped socially, and how it would impact the green and sustainable (G&S)

biofuels requirement were observed. Hence, observation assisted the researcher to understand the contents surrounding the technological change with the R&U that emerged from biofuels deployment and development, whilst identifying strategies implemented to have these R&U solved.

(c) Document Analysis

This is to analyse written materials and documents (reports, print media) published by various organisations[87]-which are the stakeholders for biofuels introduction and innovation; particularly focus in the UK. Such data consisting of excerpts from real event documentations (Patton, 2002).

The document analysis covered the UN/EU/UK and the SG policies, ranging from climate change, renewable energy, transport and biofuels. There were significant correlation and transposition from the UN-Kyoto Protocol to the EU Biofuels Directive (EUBD, 2003), and further to the UK Renewable Transport Fuel Obligation (RTFO, 2008). Additionally, the oil companies (BP and Shell) annual corporate reports/magazines/websites, and related news releases have been used as the source for secondary data.

Generally, in a common research practice, secondary data collected from document analysis; primary data collection from interview and observation are equally important. To simplify these explanations:

(i) the document analysis is used to build up basic knowledge, to answer the inquires of “what”, “who”, “when”, “where” and “which”. Some of the “why” and “how” questions were answered, but they were rather limited. The availability of the secondary data has strengthened the researcher's basic concept before the interviews were conducted; as well as providing updated information after the interviews were completed. The strength of document analysis is-these documents were written/published and made available from time to time. They record the past,

87 The UN/EU/UK government and the SG, BP and Shell and their research partners for the NGB development, the international/national social movements, learned societies and environmentalists.

present the current situation, might as well foresee/projects in the future. However, online materials mostly have such a short shelve-lives unlike the printed documents. They might be altered/dropped according to the organisational decisions. Therefore, a proper record on dates of access and the universal resource locator (URL) for these electronic materials are important to validate the source of information.

(ii) Interviews are set to gain answers for the "how" and "why" questions from the respondents. Normally, the secondary data like international/regional/national policies, and the corporate publications lack of an explanations at: "why" such decisions were made, "how" to materialise such decisions through actions, and "how" to measure the outcomes/results after such decisions have been executed. Therefore, an interview is a channel to get these justifications, to understand the motivations, interests and objectives of respective stakeholders, which led to such technological change, as well as the relation of the causes for some of the expected/unexpected R&U incurred during the process of execution.

(iii) Not only has the researcher observed the reactions from the respondent[88], the emerging themes on document analysis[89], but also experienced the phenomena on changes and hand-on field observation[90].

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88 Things which could be observed through interview:
(a) How far he/she knows about his/her subject matters/scopes of job-to strengthen the reliability of the data obtained.
(b) Through his/her explanations: What does he/she think about other companies/organisations that also one of the stakeholders (positive/negative impressions, the action and reaction).
(c) Through his/her explanations: What is the relationship between his/her organisation with other institutions (roles and responsibilities, complementing, rivalry, pressuring, power distance and relationship).
(d) Through his/her explanations: How does his/her institution interact with other institutions (cooperate, avoidance).

89 When visiting the organisational websites/media in the real time order, the researcher observed and experienced the changes of information according to the latest decisions made politically, economically and socially that aligns with the latest development of the NGB technology. For example, "combating climate change" was used during the formulation of the EUBD (2003). "Cutting GHG/CO_2 emissions" was used during the formulation and the execution of the UK RTFO (2008). While "green and sustainability biofuels" is used after the emergence of systemic risks, and will be prioritised for the existing and the NGB product/production.

90 emphasised during the emergence of two systemic risks: how the media/social groups pressured the regulators (the EU/UK/Scottish Government) and oil companies. Simultaneously, how the regulators and oil companies responded to the pressure from these social groups and media.

3.4.3 Data Collection at a Field Setting

Cooper and Schindler (2008) note that, the research design is different as to whether it occurs under an actual environmental condition (on site/field) or under other condition (laboratory with controlled condition). Easterby-Smith et al. (2004) add, field work is the study of a real organisation, where a researcher immerse him/herself and become part of the group under study, in order to understand the meanings/significance that people put upon the behaviour of themselves. This research was conducted under the field condition. Data were collected directly in the real public and private organisational through interview the SG, BP and Shell representatives.

3.4.4 Identifying and Contacting the Respondents for Interview

The researcher has conducted the face-to-face interviews with four representatives from the SG across four departments: Transport, Rural Development, Renewable Energy/Bioenergy and Communication/Media. The respondents from the SG are held the roles of manager, assistant manager or executive.

For the private sector, there was one representative from Argent, three representatives from BP and five from Shell whom are working across Biofuels Business Unit, Quality Control, General Administration, Engineering and Renewable Energy. These respondents are holding either the managerial or the technical positions which directly/indirectly involve in biofuels activities. As such, these respondents are significant for the study, since their views/opinions were strongly supported by their designations/experiences. Consequently, this helped to build a higher validity and reliability of the primary data collected.

To select these respondents, a candidate contact list was prepared from the search of their organisations' websites or through networking (seminars/talks attended). After that, an email of invitation-for-interview (if the respondents' email address were available), or a letter was sent (if the respondents' email address were not found). Both emails and letters included an Official Supporting Letter prepared by the researcher's principal supervisor-Dr. XiaoBai Shen (refer appendix 3.4.4). This letter helped to clarify the researcher's identity and to support the research. After that, a three-to-four-week duration allowed for their reply. Sometimes, a second email/letter had to be sent as a reminder. Once a candidate replied, communication was organised via email/telephone, which led to an appointment for an interview.

According to Crow et al. (2004), gaining informed consent from the respondent is central to an ethical research practice. As such, the researcher has to clarify which the data collected would be used solely for an academic research of a Ph.D degree, and not for commercial purposes. Some parts of the transcript were returned, which allowed the respondents to verify the validity of the data collected. The respondents were free to comment/alter/withdraw the information, which made themselves felt comfortable and confident for their views to be appeared in the researcher's thesis.

3.5 Questionnaire Design

The data collection was guided by two sets of questionnaire, one for the SG representatives (refer appendix 3.4.2a), with the other for the private companies representatives (refer appendix 3.4.2b). According to Warwick and Lininger (1975), relevance and accuracy are the basic criteria that a questionnaire must meet and design, in order to achieve the research objective. Besides, Zikmund (2003) suggests, the types of question and the questionnaire sequence are important for a questionnaire design. To achieve these ends, a researcher while designing a questionnaire is required to make several decisions as listed in Table 3.5.

Table 3.5: Decisions in Questionnaire Design

What should be asked?
How should each question be phrased?
In what sequence should the questions be arranged?
What questionnaire layout will best serve the research objectives?
How should the questionnaire be pretested?
Does the questionnaire need to be revised?

Source: William. 2003. Business Research Methods, pp. 330.

Zikmund (2003) stresses, the importance of a good problem definition and the clear objectives in particular, will drive a good questionnaire design. This is because the problem definition will indicate which types of information must be collected to answer the research questions.

3.5.1 Questionnaire Relevancy

A questionnaire is relevant if no unnecessary information is collected, and if the information required to address the research questions is obtained. Asking a wrong/irrelevant question should be avoided. Some of the recommended questions which could be helpful for reflexivity: "Is information being collected on the relevant respondent?" "Are there any questions that might clarify the answers to other questions?" "Will the results of the study provide the solution to the research question?" These questions are highlighted in order to capture the framework of questionnaire design (Zikmund, 2003).

3.5.2 Questionnaire Accuracy

After a researcher has decided what should be asked, the criterion of accuracy then becomes the primary concern. Zikmund (2003) defines accuracy as the reliability and the validity of the information. By using simple, understandable and unbiased wording, this could enhance the accuracy in question writing. Unavoidably, obtaining accurate answers from a respondent is strongly influenced by a researcher's ability to design a questionnaire that facilitates recalls and motivates cooperation from a respondent.

Psychologically, a respondent tends to be the most cooperative when the subject of the research is interesting; and where the questions are not lengthy, difficult to answer or ego-threatening. Under the questionnaire design process, the secondary data is used to select terms/key words[91], which the policy makers and the industrial practitioners use. The secondary data helped to strengthen the knowledge base, and to avoid information which will be obtained from reading was set as one of the questions. One of the objectives of interview was to obtain answers for "how" and

91 For example, biodiesel is named as vegetable oil by the SG representatives, biodiesel in BP, while is called FAME (Fatty Acid Methyl Ester) in Shell.

"why" questions, and to get further information which the secondary data has not justified.

3.5.3 Open-Ended Response Questions

There are many ways to phrase a question. For the construction of a questionnaire, the researcher opted for the open-ended format, which asked the respondents to express his/her opinions freely. Open-ended response questions are free-answer questions. It is most beneficial when a researcher is conducting exploratory research, especially if the range of responses is not known. Zikmund (2003) admits, respondents are free to answer with whatever is uppermost in their thinking. However, the open-ended response questions carry disadvantages too.

Firstly, the cost of open-ended response questions is substantially greater than fixed-alternative questions. This is because of the job of coding, editing and analysing the data gathered are quite extensive and time consuming. Each respondent's answer is unique. There is some difficulty in categorising and summarising the answers (Zikmund, 2003).

Secondly, the interviewer bias may influence the responses. While most instructions state that the interviewer is to record answers verbatim, rarely can even the best interviewer get every word spoken by a respondent. There is a tendency for interviewer to take short cuts in recording answers. Unfortunately, this could lead to changing a few of a respondent's words and thereby substantially influencing the meaning/results. Thus, the final answer often is a combination of the respondent's and the interviewer's ideas rather than the respondent's ideas alone (Zikmund, 2003).

In order to overcome such shortcomings, the researcher exercised precautionary steps to ensure more accurate answers could be obtained. Firstly, knowing the open-ended question does not set a limit for answers, the researcher designed the questionnaire which excluded biasness/carelessness. The questionnaire has been checked by the researcher' supervisors and being tested on two/three close friends of the researcher who are working in the SG, BP and Shell. Reflexivity and refinement of the questionnaires were carried out from time to time, to accommodate new inputs/latest information and new event emerged.

Next, even though a respondent can express his/her opinions freely, yet he/she is being guided to avoid from giving information which will deviate too far away from what the question is seeking to answer[92]. The researcher has another copy of questionnaire with sub-questions set, in order to guide the interview process and probe for further answers from the respondent.

Thirdly, one of the most important criteria which contributed to a higher accuracy of the information obtained was-the researcher was truly participative and paid full attention during the discussion. The researcher played "no presumption". Any ambiguities which was beyond the researcher's knowledge, the researcher then asked for further explanation. For example, the researcher understood the RTFO programme, yet when the Gallagher report (2008) was mentioned by the respondent, the researcher requested the respondent to provide further explanations. This is because, it is better to get the first-hand understanding from a well-informed respondent, rather to get the information and search through later. Lastly, the researcher got permission to use a dictation phone and recorded the entire interview session, while shorthand was performed simultaneously to write down the information. Not every single word has been written. The shorthand was made as a back-up when important points were made by the respondent by highlighted the key words/key messages. After parts of the conversation have been transcribed, shorthand could be used to compare with the transcripts to check for accuracy. In order to gain the validity of the data, some parts of the transcript were sent to the respondent, and he/she was free to comment, alter or to drop any parts which made him/her felt more confident on the information revealed.

92 Some of the respondents were willing to share their personal childhood stories or working history/experience which seemed to appreciate the renewables. Yet, realising that this information would not going to answer the research questions, the researcher has been cautiously guided them back to the question being discussed.

3.5.4 Questionnaire Sequence

The order of the questions may serve several functions for a researcher. Zikmund (2003) states, if the opening questions are interesting, simple to comprehend and easy to answer; then a respondent's cooperation and involvement can be maintained throughout the interview. If a respondent's curiosity is not aroused at the outset, then he/she could become disinterested and the interview would be terminated.

In an attempt to warm up respondents toward the questionnaire, Zikmund (2003) advises that a researcher frequently asks demographic/classification questions at the beginning of the questionnaire. This is generally not advisable as asking for personal information such as income level or education may embarrass/threaten the respondents. It is generally better to ask embarrassing questions at the middle or the end of the questionnaire after a rapport has been established.

For the questionnaire design, the designation and the scope of job of the respondent have been identified beforehand. Such information usually could be obtained from the organisational websites, or from information provided by the introducer for this respondent. No sensitive questions have been set which could invade the privacy of the respondent. The ultimate aim was not to know about the respondent individually, but rather his/her thoughts on issues/topics which were discussed. The designation and the scope of job of the respondent were parameters to identify the suitability/credibility of the respondent before the interview was carried out.

In addition, Zikmund (2003) reminds, order bias could distort result. Normally, the sequencing of specific questions before asking about broader issues are a common cause of order bias. Therefore, it is advisable to ask general questions before specific questions, to obtain the freest of open-ended responses. This procedure is known as the funnel technique, which allows a researcher to understand the respondent's frame of reference before asking more specific questions about the level of the respondent's knowledge.

3.6 Reflexivity: The Respondent's Perception on Interview

The researcher found out, the presence of the researcher during the interview process has affected the respondents' perception. The respondents inclined to act unnaturally and became formal and cautious during the conversation. In general, they were careful to reveal information, particularly when the researcher intended to probe further from the previous statements which they have made. Redding (1970) explains, this is because, when people in the study perceive that research is being conducted, the respondents' perceptions influence the outcomes of the research in subtle ways. Although there is no widespread evidence of attempts to please a researcher through a successful hypotheses guessing, or an evidence of the prevalence of sabotage, when a respondent believes that something out of the ordinary is happening-especially what he/she said would be recorded, he/she may behave less naturally.

There were two levels of perception which the researcher would reflect during interviews: Subjects perceive minor/no deviations and subjects perceive deviations induced by the researcher. The perceptions of the respondents were variedly behaved according to the types/functions of their business, either as a public/corporate representative. In order to demonstrate these reactions, the "Response Likert Scale"[93] could be applied, to represent the openness of the respondents.

(a) Subjects perceive minor/no deviations

There were four representatives from the SG across four departments: Transport, Rural Development, Bioenergy and Media. The Likert Scale Scores generally ranged 4-to-4.5. The respondents perceived minor/no deviations with the presence of the researcher, and they generally showed a high enthusiasm in sharing information openly during the interview process. This was mainly due to the nature operation of the SG as the policy maker, of which the main audience is the general public. Therefore, information dissemination is one of the main functions of its operations. The researcher had an easy access to these respondents, and received adequate information-which was mainly supported by the policies established by the SG. After

93 Five is the highest openness while one as the highest closeness.

the interview, the researcher was in touch with two of them for information updates. They were keen to provide more updated information which was related to their work.

(b) Subjects perceive deviations as the researcher induced

Corporate representatives (one from Argent, three from BP and five from Shell) could be evaluated with the Likert Score ranged 3-to-3.5. Most of the information shared was limited to the general/corporately published information, but strictly did not cross into any business secrecy/classified information.

One strategy which the researcher applied was to have himself adequately prepared. By reading as much as possible/as wide as possible from the corporate publications, the basic understanding of the information helped the researcher to be well-informed, which could then tap into more in-depth questions relating to “how” and “why”, and avoided irrelevant questions from being asked. Overall, some of the questions from these corporate representatives were answered well. Yet, some were not answered at all due to commercial confidentiality/classified information since the respondents were unwilling to reveal. There was a good rapport built (with one respondent from BP and two respondents from Shell). They were helpful and are still in touch to provide further updates/share internal used corporate publications/information to the researcher.

3.7 Reflexivity: Problems Faced during Data Collection and Solutions

Apart from attaining the research objectives-as an ultimate academic achievement; learning of the research skills through this research process is also one of the accomplishments. In reality, the researcher has some limitations[94]. Apart from these natural limitations, the green field of the study generates more problems that the researcher anticipated. There were three problems faced by the researcher along this

94 Issues like: the researcher is an international student, whose the first language is not English. The researcher is trained as an engineer as his first degree, but then doing social science research in Edinburgh for his PhD. The researcher also does not understand well the governance system of the UK.

"contemporary" research process: networking establishment for data collection, sociotechnological change which was dynamic/uncertain, and information which was not adequately/on-timely available. Yet, all of these have not been taken as the natural hurdles by the researcher himself. The passion about gaining knowledge, a willingness to learn and the courage to conduct an entirely new study in a foreign country could never have materialised without the support of the researcher's supervisors, family members and friends.

3.7.1 Networking Establishment

There were four representatives[95] from the SG. Compared with the oil companies, the researcher had easy access to these respondents, received adequate information that was mainly supported by the policies established by the SG. However, to establish networking in the oil companies was never easy. This networking building was the most challenging assignment before the data collection could began. It was trying, challenging and time consuming. The researcher took more than a year to find the right person who was working directly/indirectly in biofuels[96].

The problems were resolved once the researcher obtained information about BP through the Edinburgh University Business School Alumni. Besides, the participations of the researcher in some of the seminars/talks organised by the Business School where oil representatives were invited as the speakers were helpful. Furthermore, through a friend of the researcher who is working at Shell (working across projects in Malaysia, Singapore and Dubai), the accession into Shell UK was finally established. Inevitably, "who do you know" played the ultimate factor for networking expansion. Introduction from one respondent to his/her colleagues, one-

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95 These four SG representatives are those who working on biofuels directly/indirectly. Initially there were six interview conducted. Two have been rejected by the researcher after the data collected due to the data obtained were not related to biofuels, rather they were centred around: RE generation (wind farm, tidal), media and campaign for eco-driving.

96 Three representatives from BP and five from Shell are those who working closely related or directly on biofuels. Initially, there were eleven interview conducted. Three (two from BP and one from Shell) have been rejected due to the results obtained were not suitable for the study. The information obtained centred around: consultants working for these oil companies, and engineers working off shore.

by-one was time consuming and fragile. The discontinuities happened many times and it was trying. However, reflecting on the process, it was a rewarding learning curve. The networking was finally established to both the regulator and the oil companies' representatives.

3.7.2 Dynamics of Sociotechnological Change

Data collection through interviews officially began on 1 April 2008 and ended on 30 September 2009. The researcher has travelled to Edinburgh, Glasgow, London, Aberdeen and Dundee; met up with the respondents according to the appointments set. There were three important events which occurred during this interview period. Firstly, the early period of the RTFO execution; Secondly, when the systemic risks responded by the UK Government on 7 July 2008[97]; and thirdly, the period after the systemic risks were cooled down beyond 15 September 2008[98]. The marking of these important dates was aimed to highlight the emergence of new inputs, which the researcher had to take into consideration when interviews were conducted.

Biofuels deployment and development are contemporary and evolving with the technological change. These two processes are complex and uncertain. The main drawback for interviews conducted during the RTFO early execution was, that they seriously lacked feedback for the deployment process. Most of the information gained was related to the pre-deployment of the RTFO, most of which could be gained through the document (regional/national policies, corporate reports) analysis.

During the emergence of the two systemic risks (food-fuel competition and biodiversity threatened) which was amplified by the international/national pressure groups and media, the UK Government responded to this issue and declared on media publicly to slow down the biofuels expansion in the UK. This was a new input

97 On 7 July 2008 marked the official date, where the UK ex-Transport Secretary Ruth Kelly announced the decision to slow down biofuels expansion in the UK. Two months later, this was followed by the alteration of the RTFO targets after the publishing Gallagher Review (2008).

98 which marked the date of the media/public attention was switching from the biofuels debates to the world financial downturn after the bankruptcy of the Lehman Brother.

which had to be taken into consideration for the interviews. However, during this period of time, most of the respondents (the SG, BP and Shell representatives) were unable to provide any precise and definite answers on the counteracting strategies/actions, apart from commented that, more evidence would be required and analysed before any decision could be made.

The real situation was, two-month after the news, many respondents were unsure and uncertain as what should be done next. The oil companies' representatives generally were waiting for decisions/instructions made from the EU/UK government. They refused to comment about the systemic risks occurred. Meanwhile the SG representatives were also lacking information, and were waiting for more evidence. Only after 20 September 2008, the researcher was able to obtain a copy of the Gallagher Review with the conclusion: biofuels would continue, but the RTFO targets are revised to slow down the biofuels expansion in the UK. Furthermore, more stringent requirements for the green and sustainable (G&S) criteria will be enforced and emphasised on biofuels supply which is controlled by the RTF Certificate and the Renewable Fuel Agency "Carbon and Sustainability" monthly reporting system must be obligated to be complied by biofuels producers and suppliers (refer appendix 4.1.4).

On 15 September 2008 marked another important date for the research's data collection. It was the day where the global media announced the bankruptcy of Lehman Brothers Holdings Inc. This switched the British public's attention and the media concentration from the biofuels controversy to the beginning of the global financial crisis. This was the period where the biofuels disputes/systemic risks were cooled down. Apart from the pressure groups which continued their agendas against biofuels, the media showed more interest on the financial crisis which had a higher news value. Some interviews conducted after this date had begun to take in this new issue, and to investigate whether this financial crisis has affected the NGB development projects.

Given the deployment process which did not generate adequate feedbacks for the execution, and the emergence of systemic risks and then the financial crisis; each of these events added to the complication of the research. Hence, conjectures about certain aspects are unavoidable. To overcome these problems, the researcher re-invited all respondents to conduct a second interview. Only two[99] from the SG and one[100] from Shell responded to the invitation. Even though more than half invitations were turned down[101], fortunately, some are still being helpful to be in touch with the researcher, and sending in (through email/post) new information. Two representatives from BP and two from Shell were supportive and shared the most updated publications (internal use/circulated corporate magazines, classified reports) with the researcher. Without their help, further updates would be more challenging, as much of this information was not publicly available.

3.7.3 Inaccessibility of Updated Secondary Data

As expected, the openness of the SG representatives was positive. Much information has been obtained during interviews. However, the efficiency of their publications was rather low, particularly for the latest information/updates after the RTFO targets were reduced to slow down biofuels expansion in the UK. However, the openness of the corporate companies' representatives was low due to information reservation. Despite the fact that, they have higher efficiency on their publications; yet it is the matter of accessing the latest information. Latest information is hardly to be obtained/accessed by the public without knowing someone who is working for the organisations.

Information relevant to the pre-commencement of the RTFO was more than adequate to support the first three research objective (refer section 1.2) particularly the policies formulated for biofuels deployment. However, after the commencement of the RTFO

99 Executive of Renewable Policy Team, Policy Manager of Cleaner Vehicles and Alternative Fuels
100 Executive in the Shell CO_2 Abatement Project.
101 The reasons to turn down the second invitation for interview: No further updates from his/her organisation; the RTFO alteration/systemic risks/global recession did not impact his/her organisation, no adequate information which he/she could share, or personal reasons such as uninterested.

and the subsequent systemic risks emerged, the researcher faced difficulties in getting the relevant information and latest updates. With no specific date of release (from regulators) and no guarantee for public access (from oil companies), one of the toughest challenges which the researcher faced was catching up the up-to-date development surrounding the RTFO executions, the R&U incurred, the systemic risks emerged and the strategies that were implemented to have these R&U resolved.

The delay in publication of official reports is a normal practice in public administration. Most of the issues would be fully investigated by some independent consultants (appointed by the UK/Scottish government), while the evidence/conclusions would only be published few months later. Sometimes, it could take up a year or two for the report to be finally published[102]. Meanwhile, corporate publications are restricted for internal circulation/use, and not for releasing to the general public. Unless it is reported in their annual report which is publicly available to attract investments; most of the latest information is confined within the organisation and would be termed secured/classified business information.

Since the secondary data is a complementary source to support the primary data and to enrich the information for the research subjects; the researcher paid serious attention to the availability of this information. Firstly, the researcher used Google search engine to find the latest information[103] every day. Secondly, the researcher watched BBC News daily and read online/purchased newspapers or visited each organisations[104] website once per week. Thirdly, for documents which were not accessible, the researcher contacted the respondents and requested the publications[105]

102 For example a report from AEA Technology, about Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland, 1990-2006, was released in September 2008. Besides, the Gallagher Review was published in July 2008, but only made available to the public in November 2008.

103 The keys words put into string: biofuels, the next generation biofuels R&D, the EU/UK Government biofuels, the Scottish Government biofuels, BP biofuels (year), Shell Biofuels (year), the RTFO, the 2G biofuels, the 3G biofuels, algae biofuels, food-fuel competition, biodiversity threatened, world hunger biofuels, green and sustainability biofuels and roundtables.

104 the UN/EU/UK/Scottish Government, BP, Shell, and related pressure groups (like the Friends of the Earth, Oxfarm, the Royal Society) biofuels roundtables and others.

105 Articles, reports, magazines, policies, news release which were obtained from the print media and

as well as opinions from them.

3.8 Data Analysis

Data analysis refers to the practical application of investigative procedure in social science data. It is concerned with familiarising a social researcher to the use of interpretation/evaluation of relevant data; in order to arrive at a better understanding of social processes (Rose and Sullivan, 1996) and to achieve the research objectives. Since open-ended questions were used for data collection, the researcher has to manage the raw data collected efficiently. Recognising that each of the respondent's answers were unique, there were some difficulties in categorising and summarising the answers accordingly. However, some could be easily arranged since they showed some significant patterns of coherency.

The researcher has gone over questions, and classified the information collected according to the classification scheme. These schemes were mainly based on the research objectives, and set as a guide to counter-check whether information has been collected, has answered the research questions appropriately and achieved the research objectives accordingly. Although it was an extensive and time consuming process, the uniqueness and the rich information obtained from the open ended questions helped to fill up the gaps and the ambiguities.

Miles and Huberman (1994) define data analysis with three concurrent flows of activity:

(a) Data reduction: a form of analysis that sharpens, sorts, focuses, discards and organises data in a way that final conclusions could be reached and verified. For examples: the primary data obtained has been organised by the researcher, to show the flow of explanations/justifications, and information was managed and presented to ensure it appeared in a concise manner. Furthermore, the secondary data such as policies, corporate reports were organised to depict the chronological flow of biofuels deployment and development, while the political/corporate messages were

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the internet gateway.

focused to draw out the most important substance for such technological change.

(b) Data display: an organised, compressed assembly of information that permits conclusion to be drawn. The displays in this thesis include many types of figures, tables and models; as all are designed to assemble information which could be presented in a clear/concise manner.

(c) Conclusions are verified as the analyst proceeds. Verification may be as fleeting second thought crossing the analyst's mind during the writing-up phase, with a short excursion back to the field notes. Next, it may be thorough to elaborate argumentation and reviews to develop inter subjective consensus. Thus, the latest information for technological change has been searched. Information from the secondary data (that set up the basic knowledge) was combined with the primary data which strengthened the justifications to answer why such decisions were made and actions were taken. This information was substantial to construct a comprehensive overview, and to ensure a sound/concrete conclusion could be drawn.

3.8.1 Analysing Data for Case Study

Proposed by Yin (1994), there are four dominant analytic techniques:[1]pattern matching, [2]explanation building, [3]time series analysis, and [4]program logic models. Each is applicable whether a study involves a single/multiple case design. The ultimate goal is to treat the evidence fully, to produce compelling analytic conclusions, and to rule out alternative interpretations. The researcher study was analysed through explanation building and time series analysis.

In these cases studied, explanation building has appeared mostly in descriptive form. The driving forces, mechanisms, roles and responsibilities, interactions built between the regulators and the oil companies to implement biofuels deployment and the NGB development are under investigation. Mean while strategies implemented to counteract with the R&U of these two processes were also being studied.

A time series analysis was also adopted. According to Yin (1994), it could be much simpler in one sense, yet the pattern can be more complicated in another sense, because the multiple changes in this variable over time may have no clear ending point. With the focus on technological change which was centralised on the issue of biofuels deployment and development; clearly, there was a need to clearly divide these into two different periods of time. From this, the research could concentrate in biofuels deployment as well as in development stages, while the different R&U emerged through the different processes and the strategies implemented could be researched. Therefore the time series was a guide which allowed the researcher to build on explanation and description for the analysis. These time series were not rigidly apprehend in chronological sequence, but rather a conceptual flow which postulated different stages of biofuels, and segregated the mass of the information collected, to a more logical way of analysis and data presentation.

Yin (1994) further comments, the logic underlying a time series analysis is the match between a trend of data points compared with (a) a theoretically significant trend specified before the onset of the investigation, (b) some rival trend, also (c) any trend based on some artefact or threat to internal validity. Due to the strength of case study which able to trace socio-technical changes over time[106], it enables the study of relationship of events over time.

3.9 Validity, Reliability and Generalisability

Easterby-Smith et al. (2008) claim, there is an underlying anxiety among researchers of all persuasions that the research will not stand up to outside scrutiny. This is very understandable since research papers and theses are most likely to be attacked on methodological grounds.

The technical terms for validity, reliability and generalisability are varies with the philosophical viewpoint adopted during the research design. Easterby-Smith et al. (2004) summarise some of the differences between positivist, relativist and

106 which does not limited to cross-sectional or static assessments of a particular situation.

constructionist viewpoints. Due to the philosophical stand of this research was grounded on social constructivism, the researcher has picked up the elaborations as shown in Table 3.6.

As Kirk and Miller (1986) point out, the language of validity and reliability was originally developed for use in quantitative social science, and many procedures have been devised for assessing different facets of each. Classic text books on methodology distinguish between three main kinds of validity: construct, internal and external validity. However, Easterby-Smith, et al. (2004) explain, their definition of validity is similar to the concept of construct validity, and the notion of generalisability is similar to the traditional definition of external validity.

Table 3.6: Perspectives on Validity, Reliability and Generalisability

Parameters	Constructionist	Case Study Tactic	Phases of Research in which Tactic Occurs
Validity -Construct[107] validity	Does the study clearly gain access to the experiences of those in the research setting?	-Use multiple sources of evidence -Establish chain of evidence -Have key information review draft case study report	-Data collection -Data collection -Composition
-Internal validity[108]		-Do explanation building -Do time series analysis	-Data analysis -Data analysis
Reliability[109]	Is there transparency in how sense was made from the raw data?	-Use case study protocol -Develop case study data base	-Data collection -Data collection
Generalisability /External validity[110]	Do the concepts and constructs derived from this study have any relevance to other settings?	-Use replication logic in multiple case studies	-Research design

Source: Combination of Yin (1994) pp. 33 and Easterby-Smith et al. (2004) pp.33.

107 whether the instruments are accurate measures of reality (Easterby-Smith et al., 2004).
108 whether the research design is capable of eliminating bias and the effect of extraneous variables (Easterby-Smith et al., 2004). It shows the establishment of a causal relationship, where by certain conditions are shown to lead to other conditions, as distinguish from spurious relationships (Yin, 1994).
109 Demonstrating that the operation of a study, where the data collection procedures can be repeated, with the same results (Yin, 1994).
110 involves defining the domains to which the results of the study may be generalised (Easterby-Smith et al., 2004).

3.9.1 Construct Validity and Internal Validity

In terms of validity, some argue that qualitative research has higher validity, because it stays closer to the real meaning of social existence than quantitative research that produces numerical findings (Baker, 1999).

For case study, according to Yin (1994), several tactics have to be used in dealing with these requirements, and the tactics should be applied throughout the conduct of the case study. Besides, the data analysis needs to be complemented with triangulation-a way of examining insights gleaned from different informants/sources of data. By drawing on other types and sources of data, observers also gain a deeper and clearer understanding of the setting and of the people being studied (Taylor and Bogdan, 1998). Furthermore, Lewis and Ritchie (2003) note that triangulation assumes that the use of different sources of information will help to confirm and to improve the clarity/precision of a research finding. This also allows the data to be explored from a different viewpoint/perspective, while the risk of bias could be reduced.

Denzin (1978) and Patton (2002) provide a good understanding on triangulation which consists of:

(a) Methods triangulation: Checking out the consistency of findings generated by different data collection methods.

(b) Triangulation of sources: Checking out the consistency of different data sources within the same method.

(c) Analyst triangulation: Using multiple analysts to review findings.

(d) Theory/perspective triangulation: Using multiple theoretical perspectives to interpret the data.

They insist that by triangulating with multiple data sources, methods, and analysis; a researcher can make substantial strides in overcoming the scepticism that greets singular methods, bias analysts, and single perspective interpretations. The researcher has utilised three data collection methods, which triangulated the method from:

(a) Interview: not only has it obtained primary information relevant to the SG, BP and Shell respectively on biofuels deployment and development, but it also gained cross information[111] from each of the respondents' views/opinions about other respondents or issues discussed. The cross information seeking provided some insights, enabled the researcher to understand the respondents' views and the interactions between two parties. The richness of the information generated has established a chain of evidence that strengthen the validity of the study.

(b) Observation: from the media streaming, the researcher looked at a larger picture to comprehend the sociotechnological change which incurred R&U during biofuels adoption and development.

(c) Document analysis: the documents which served as the sources of secondary data were highly reliable. They were published/produced from the organisation, which signified the quality of reliableness and trustworthiness. Besides, document analysis has bridged the logical link between facts and other evidence found through interviews and observations.

3.9.2 Reliability

The objective is to be sure that, if a later investigator followed exactly the same procedures as described by an earlier investigator and conducted the same case study all over again, the later investigator should arrive at the same findings and conclusions. The goal of reliability is to minimise the errors and biases in a study (Yin, 1994).

One prerequisite for allowing this is the need to document the procedures followed in the case study. Baker (1999) advises, a research is required to strengthen the

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111 For example, opinion from the respondent A was used to gain feedbacks when interviewed the respondent B. The respondent B was free to comment what he/she thought about comments made by respondent A, as well as issues raised from media, and quotations from the significant representatives such as environmentalists, academicians, politicians and others.

reliability of a case study, where he/she must carefully document each step in research design and data collection in a case study protocol. According to Yin (1994), a protocol is a written plan (notes and audit trail), containing the instrument, procedure and general rules based on a comprehensive outline of how the study will be carried out.

The researcher kept a case study protocol which accommodated information such as case study data base, case study materials and record for latest information. This was encouraged by the researcher's supervisors, to make sure records were clearly made, to testify the sources of information.

3.9.2.1 Developing a Protocol for the Case Study

Yin (1994) suggests, the protocol have the following sections:

(a) An overview of the entire project, which includes the objectives, issues, and the literature reviews that are relevant to the case study.

(b) A description of field procedures, including form of access, relevant credentials, sources of information and various reminders of how to operate in the field.

(c) The questions to be answered in the study, which will guide the data collection and suggest sources of information for answering the questions.

(d) The guide for preparing the final case study report. This written protocol guides the entire research efforts.

The protocol then performed as a guiding instrument. It reminded the researcher what the case study is about. Yin (1994) advises, the preparation of the protocol forces an investigator/researcher to anticipate several problems, including of how the case study reports might be completed. The audience for such report will have to be identified, even before the case study has been conducted

3.9.3 Generalisability

Yin (1994) admits, the case study method has the critical limitation to prove whether a study's findings are generalisable beyond the case study. This is because the factor of localisation has shaped the research, from the beginning of the research ideas/concepts to the conclusion which is going to make.

Yin (1994) backed the case study method with "analytical generalisation". This method allows a researcher to generalise a particular set of results to some broader theory. However, the generalisation is not automatic; whilst a theory must be tested through replications of the findings in a second/third study. Once such replication has been made, the results might be accepted for a larger number of similar studies. This replication logic is the same that underlies the use of experiments, and allows scientists to generalise from one experiment to another. Hence, through case study, the first step on theory building is setting up propositions to link the data to be collected (Baker, 1999).

At the end of the analysis, the novelty is to produce a theory. According to Langley (1999) theory building involves three processes[112], yet for this research it was the induction process, which empirical research generalisation towards theory building. According to Rose and Sullivan (1996), induction begins from particular observations from which empirical generalisations are made, as these generalisations then form the basis for the theory building. As such, Patton (2002) claims that inductive analysis involves discovering patterns, themes, and categories in one's data where findings emerge out of the data, through the analyst's interactions with the data.

3.10 Conclusion

In this chapter, the researcher has discussed the issues in deciding the appropriate methodology for this research. The researcher has identified the paradigm as a social constructionism-which provides a high degree of social interaction and involvement from the SG and the oil companies within the biofuels regulated market. This allowed the researcher to access different data sources and information, which has

112 (a) Induction (data-driven generalisation), (b) Deduction (theory-driven hypothesis testing), and (c) Inspiration (driven by creativity and insight) (Langley, 1999).

the potential to obtain new insight into the research. Besides, the researcher concluded that the research falls into an exploratory type because it fulfilled the research purpose (explorative on green field), while case study approach was adopted to conduct the research-intensively helped the researcher to understand the research phenomenon of the technological change with attempts to deal with the cases in an in-depth study.

Throughout the research process, the researcher opted for three data collection methods-interview, observation and document analysis; with two methods of analysis-explanation building and time series analysis. All of these methods of analysis enabled the researcher to link data to propositions and interpreted findings towards theory building, which complied with the requirements of validity, reliability and generalisability.

The research outcomes have attained the research objectives and answered the research questions, within the process with a trying condition. If the researcher had a chance to repeat the research process-the social constructivism, qualitative, case study would still be opted. Yet, some other considerations would be taken into account to enable the research to be conducted in a more effective way. Then, more efforts could be spent to deal with the actual challenge of the data analysis and not the process of data collection which took long time to search for the right respondent. Some of the considerations include:

(a)To conduct data collection a year after the RTFO execution. This longer period would allow more concrete information/feedback to be obtained, and would not require repetitive interviews to get further information.

(b)To conduct a focus group rather one-to-one interview. The focus group could lead to more generated information, where the interactions among respondents could create momentum and be dynamic to allow the topic to be explored and expanded. Besides, the respondents' perceptions would be lowered, since the environment would be interactive-and more discussions rather than rigidly operated within modes of question-and-answer session.

Indeed, to conduct a successful interview, adequate preparation is the critical factor. Advocated by van Maanen (1983) and Strauss and Corbin, (1990), qualitative research requires thinking abstractly; critically analysing situations; avoiding biases in order to obtain valid and reliable information. Personally, a successful interview is not only enabling a researcher to answer the research questions, but is also benefiting the respondents at the same time. Through this research, it provided a platform for information sharing. It bridged between the academic knowledge and industrial practical experiences, where both parties could gain mutual benefits.

Chapter 4 Governments Policies in Shaping the UK Biofuels Deployment and Development

Preface

Since the UK is a unitary state with a devolved system of government, the UK biofuels deployment is determined by the UK Government and influenced by the EU Government. However, biofuels implementation in Scotland is not a single cell decision of the Scottish Government (SG). The existence of the EU and the UK Governments' influence the multiple roles the SG plays-not only as one of the regulators, but also as the executor of biofuels adoption and innovation in Scotland. Under the Devolved Matters, the defined scopes of function allow the SG to have its sovereignty over decisions made on the NGB development. As a result, numerous the NGB pioneering development projects are established and executed by the SG within its own political authority. Therefore, the EU and the UK Governments have influenced the SG's actions, and shaped most of the UK/Scottish biofuels policies. This is important to ensure that Scotland-as a part of the UK, is aligned with the national agenda and complies with the EU Single Market Principle under the European Economic Community.

There are many policies formulated at the UN/EU/UK levels which are interwoven, and are driving forward the awareness for climate change. One of the targeted areas is for a low-carbon transport system. Under biofuels deployment/development, there are few significant policies which commenced them. This chapter will discuss the flow of the related policies, their proliferation leading to the UK biofuels deployment, and to the SG's pursuance on the NGB development.

4.1 From Kyoto Protocol to EU Biofuels Directive

On 31 May 2002, the EU Government ratified the Kyoto Protocol (refer appendix 4.1.1). The twenty-five EU Member States[113] collectively agreed and obliged to comply with their respective national GHG emissions targets, in order to achieve the

113 Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, the UK.

overall EU target of 8% GHG reductions (compared against 1990 as the base year) by 2012.

After the Protocol ratification, it was the beginning of the EU policies formulation, which brought together different methodologies/plans/strategies in order to achieve the regional target. There are many sectors which needed to be catered for, mainly power generations, industrial/commercial/household energy use and transport system. According to the Commission of the European Communities (2006), emissions resulting from regional transport accounted for 21% of the total emissions of GHG in the period of 1990-2001. As a result, it is necessary to use fuels that are less polluting than oil. Two regional policies which focus for regional road transport GHG reductions are the Directive on the Promotion of Biofuels (DPB) 2001, which subsequently became the EU Biofuels Directive (EUBD) 2003.

The DPB (2001) deals with the issues of energy security and the GHG reduction (refer appendix 4.1.2). To tackle these two considerations, the DPB (2001) suggests three potential alternative ranges of fuels-biofuels, natural gas and H_2; that each could be developed up to the level of 5% (or more) of the total automotive fuel market by 2020. However, biofuels has been strongly favoured in preference to the other two alternatives.

Analysing the EU policies, the driving force behind the long-term substitution of conventional diesel and gasoline is the need to improve the long-term security of energy supply; as well as to reduce the environmental impacts from the transport sector. Any future regional policy development will continue to give higher priority to these two areas, while any long-term political solutions/actions will have to offer a reduction in oil dependency as well as a reduction in GHG emissions (DPB, 2001). Even though natural gas produces a lower carbon emission, it is still a fossil product which will be depleted over time.

Under the operation of the transport sector, the requirements of comfort, confidence, performance of the vehicle (fuel efficiency), security/availability of the fuel supply, low environmental impacts, high level of safety and the overall low cost of driving are high on the list of requirements. Penetration of any new transport fuel technology is fundamentally dependent upon its broad availability, ease of accessibility and price competitiveness. Establishing a strategy covering a fuel supply system is expensive and only could be justified if there is sufficient demand. This situation makes any new fuel/engine technology take-off difficult. Comparatively, H_2 fuel cell is the most complicated alternative, requiring an alternative engine technology, a large investment in plant to produce H_2, as well as a totally new distribution system (DPB, 2001). Thus, shifting to a H_2 based transport system is a major decision, which is not only costly, time consuming, but also full of risk and uncertainty (R&U).

As a result, it seems any radical change in the fuel/engine technology for road transport would face a number of challenges. This is because, any alternative fuel/engine technology will have to be made economically competitive in order to penetrate the market. Different alternatives (biofuels, natural gas or H_2) will require different types/levels of investment in infrastructure and equipment. However, replacing a small percentage of diesel/gasoline with biofuels is the simplest method. Besides, establishing plants to produce biofuels is the long-term investment which is considered economically viable. Ever since the first oil crisis in 1973, biomass has been adopted; and in some cases promoted, as an alternative to hydrocarbon as a source of energy (DPB, 2001).

In principle, the European Commission believes that biofuels offer an ideal alternative when based on EU grown crops/organic waste. Using biomass as a by-product is practical and CO_2 neutral since their carbon content is captured from the atmosphere. In addition, the EU Government believes that by creating an EU market for biofuels, this would offer an opportunity for the Candidate Countries [114] for increased regional trade. On average, these Candidate Countries have more agricultural land and less diesel/gasoline consumption per capita than the present EU

114 Iceland, Croatia, the Former Yugoslavia of Macedonia and Turkey.

Member States (DPB, 2001).

The European Commission also acknowledges that biofuels are expensive (at approximately €300/1000 litre). Besides, their direct/indirect energy consumption during the crops growing and fuels production mean that more than half of the CO_2 benefit is offset in the production process. However, the DPB (2001) is convinced that, these two problems could be reduced by tax incentives[115], and also by fuelling the production process with waste material from the crops for example straw-which is one of the 2G biofuels feedstocks. Even though the 1G biofuels will hardly be seen as a long-term high volume solution for motor fuels due to the limitations of agriculture capacity and available land, the 1G deserves to be exploited in the medium-term while waiting for the 2G biofuels to be commercialised. This is because biofuels could be used in the existing hydrocarbon vehicles and hydrocarbon distribution system which do not require expensive investments (DPB, 2001). Until the next generation biofuels (NGB) is commercially available, the 1G is a medium-term technology implementation, which allows transition to the NGB to take place.

Finally, a requirement for a defined minimum percentage of biofuels against all fuel sold throughout the EU was outlined by the DPB (2001). As the first step, a minimum biofuels share up to 2% was suggested. This figure was suggested in order to create a stable market, require the gradual establishment of biofuels production, and to allow for valuable experience to be gained before the next steps on biofuels expansion become effective. The European Commission believed, the most effective way of promoting large-scale biofuels penetration would be through obligatory blending of a certain percentage of biofuels into gasoline/diesel marketed throughout Europe. This solution requires no modification of existing vehicles, and it takes advantage of the existing fuel distribution system with practically no additional cost.

115 Tax incentives provide an effective way of promoting the development of biofuels by helping to reduce the differences in production costs with hydrocarbon fuels. The European Commission and the Council therefore have to adopt a framework, in order to reduce excise duty on biofuels under fiscal control. Article 14(1) (b) and (c) (biomass and waste), it gives Member States the option of reducing/exempting excise duty on biofuels (DPB, 2001).

After two years of planning by the DPB (2001), the EUBD (2003) was finally formulated. The use of biofuels for road transport forms a part of the package in order to comply with the Kyoto Protocol on the road transport GHG reductions, promote energy security and to prosper the agriculture industry. Since most vehicles currently in circulation in the EU are capable of using a low biofuels blend (5-10% by volume) without any problem, the European Parliament called for:

i. A reference value for biofuels target shall be 2%, calculated on the energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2005.

ii. A reference value for biofuels target shall be 5.75%, calculated on the energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2010.

According to the Renewable Energy Progress Report (2009), tax incentives and biofuels obligations (targets) remained the two most common instruments used by the EU to encourage its Member States in biofuels adoption. Since 2005, the European Commission has started legal proceedings against Member States for non-compliance with the EUBD (2003). The European Commission has the power to launch infringement proceedings against any Member State that fails to comply with reporting obligations (under the Article 4), or failure to set national objectives incompliance with the references values of the Directive.

Even though the EUBD (2003) outlined the targets up to 2010; in the long-term, biofuels will still play a significant role in supporting the regional road transport system. This is further evidenced by the EU Renewable Energy Directive (EURED, 2009), which obligated a 10% renewable energy in transport target to be met by 2020. This target is primarily expected to be met through the use of biofuels (RFA, 2008). The Department for Transport (DfT) is expected to incorporate the directive into the UK law in 2011 (RFA, 2010b).

4.1.1 The UK Government Strategy to Promote Biofuels Deployment

(a) Renewable Fuel Transport Obligation

The Renewable Transport Fuel Obligation (RFTO) was commenced nationwide by the UK Government on 15 April 2008. It transposes the EUBD (2003), and places an obligation on suppliers of hydrocarbon (who supplies excess of 450,000 litres of hydrocarbon per year); to provide evidence that a proportion of the road fuels they supply in the UK comprise biofuels. The effect of this was to require 5% by volume (5.75% by energy) of all UK fuel sold on UK forecourts will source from a renewable source by 2010/11. The initial target started at 2.5% by volume in 2008/9 (RFA, 2008), will be increased to 5% in 2010/11.

(b) Fuel Duty Incentives

The UK government supports biofuels through fuel duty incentives. Biodiesel and bioethanol are taxed at 20p per litre less than petrol and diesel. From the interview, the Policy Manager commented: “The incentive is supporting the market. Biofuels have to be cost effective very quickly, as they have to be paid by their own way. I think we probably need to some extent, at the beginning, to sustain the fuel demands (of biofuels) by keeping the price artificially low. However, because of the subsidy, this is obviously is not cost effective.” The biodiesel incentive has been in place since July 2002, while the bioethanol has been in place since January 2005. The aim for this incentive is to keep the biofuels’ costs low, and thus affordable for the consumer (RFA, 2008). This incentive support is guaranteed until March 2010, to guarantee cost effectiveness.

(c) Promoting the Benefits of Biofuels through Media

The “blendable” characteristics of biofuels mean they can be mixed with petrol/diesel, and immediately used in the conventional vehicles, resulting in an immediate reduction in road transport GHG emissions. A 5% biofuels use could reduce between 2.5%-4% of CO_2 emission from vehicle tailpipes. This is strengthened by the Post Note from the UK Parliamentary Office of Science and Technology (2007), “When the RTFO achieves 5%, the estimated reduction in GHG emissions equates to taking 1 million cars off the road.” Since biofuels adoption does not require engine modification, while the prices are subsidised by the incentives; the urgency of GHGs reduction is justified by these economic concerns. The benefits of biofuels on environmental issues (to reduce GHGs), social issues (for better public health) and on economic grounds (more biofuels related jobs) have been promoted through the UK/Scottish Governments' organisational media (mostly on their website), and is highlighted by the policies formulated.

(d) Promoting the Automobile Warranty of Biofuels Use through Media

Scientific publications from the biofuels suppliers/oil companies, automobile manufacturers and the regulating bodies affirmed that, the low blend of biofuels used (approximately 5%) will not have an adverse effect for the existing internal combustion engines (ICEs).

According to a public report from the Low Carbon Vehicle Partnership (LCVP, 2005) “A maximum of 5% bioethanol and 5% of biodiesel can be blended into conventional petrol and diesel respectively without invalidating vehicle warranties, or exceeding the limits in the European standards for petrol/diesel”. The limit for ethanol is also shown in the EU Fuels Directive 2003/17/EC and the UK Motor Fuels Regulations (on Composition and Content). Besides, there are some supporting publications from the reputable organisations which are highly reliable and regarded. The Frequent Ask Question from the RFA's (2009) website states: “Good quality biofuels (which comply to the biodiesel standard EN14214 and bioethanol standard EN15376) are used in low level blends for 5% presently showing no problems for engines”.

The UK Petroleum Industry Association (UKPIA, 2009) states: “The EU Fuel Standards currently limit the concentration of biofuels content of conventional petrol to 5% ethanol by volume and diesel to 7% biodiesel by volume, without affecting the vehicle manufacturer’s warranty.” Meanwhile, the European Automobile Manufacturers' Association (2008) and Worldwide Fuel Charter Committee (2009) provide the warranty statement “It is an acceptable limit for lower level ethanol and biodiesel blends; for blends between 5 to 10%.” Consequently, the warranties from the automobile manufacturers as promoted by respective bodies have increased the publics’ confidence on biofuels adoption.

(e) Compliance to the European Biofuels' Standards

The quality control of biofuels is important for the public acceptance. Since biofuels are newly adopted, most of the biofuels used in the UK are obtained through international trade. Motorists are particularly concerned about the quality of the biofuels they use in their vehicles to avoid engine damage.

To standardise the specifications, the UK Government specifies two European Biofuels Standards: the Biodiesel Standard EN 14214 and the Bioethanol Standard EN15376 which the biofuels producers are obligated to comply with. According to the UKPIA (2009), the regional automotive and oil industries, along with some international biofuels producers, have developed a European standard since in 2001. This standardisation allows for the unification of quality, and to facilitate regional trade amongst member states by ensuring that biofuels meets the requirements of existing/modern ICEs performances.

With these strategies in place, the introduction of biofuels as the new fuels has gained a high social acceptance at an early stage which subsequently eased their deployment. The fiscal policy for a tax incentive at 20p/litre is aimed at ensuring biofuels is cost effective. The compliance to the European Biofuels Standards is for technical and quality unification. Besides, the automobile warranty for low blend biofuels from the European, Japanese and Korean Automobile Manufacturers' Association, and the high frequency and wide coverage of media to promoting the benefits of biofuels have contributed to the social confidence for biofuels adoption.

4.1.2 Renewable Fuels Agency to Manage the Renewable Fuel Transport Obligation

The Renewable Fuels Agency (RFA) is a public body created by the DfT to implement and manage the execution of the RTFO. The agency is responsible for awarding the Renewable Transport Fuels (RTF) Certificates to biofuels suppliers in the UK. These certificates act as a control mechanism, ensuring biofuels suppliers could meet their annual obligated targets and comply with the "carbon and sustainable" monthly reporting system.

(a) The "Carbon and Sustainable" Monthly Reporting System

The RFA requires details of Carbon and Sustainability reporting by the oil companies/biofuels suppliers under the RTFO scheme. The RTF certificates are issued to biofuels suppliers only if they submit their report to the RFA every month. These reports detail: the types of feedstock, the country of origin, land use information, biofuels sales data, sustainability standard, and the lifecycle carbon savings of the biofuels compared with the hydrocarbon they replace. Since biofuels can come from anywhere across the globe, the suppliers need to provide publicly available information on the information of the biofuels used. This is to encourage suppliers to source biofuels which genuinely have environmental benefits, rather than using the cheapest biofuels available which might not be sustainable.

Meanwhile, the RFA also operates/administers an internationally acclaimed "Carbon and Sustainability" reporting system. The agency is responsible for publishing updates/progress the work of the RTFO, including progress on achieving compliance with sustainability criteria. This is achieved by publishing monthly and quarterly reports[116] to the DfT and producing annual reports to the UK Parliament.

(b) The RTF Certificates

According to the RFA (2010a), operating under the RTFO, fuel suppliers can meet their obligation in a number of ways, either:

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116 According to the RFA (2010b), the RTFO reports include information on:
- volumes of fuel by fuel type (biodiesel, bioethanol);
- volumes of fuel by feedstock;
- volumes of fuel by country of origin;
- volumes of fuel meeting Meta/Qualifying sustainability standards (refer appendix 4.1.3);
- life cycle GHG savings of fuels.

(i) by supplying biofuels and claiming/redeeming certificates through the "Carbon and Sustainability" reporting system, or
(ii) by redeeming certificates obtained from other biofuels suppliers, or
(iii) by paying a buyout price.

Fuel suppliers are awarded the RTF Certificates (refer appendix 4.1.4) for each litre of biofuels, which the certificates can be traded. If suppliers fail to meet their targets, they will either have to buy more RTF certificates from a third party (other biofuels suppliers) to cover the shortfall, or pay a penalty buy out price [117] to the UK Government. These certificates set out the powers and duties of the RFA, as the administrator of the RTFO, and the civil penalties that it may impose following non-compliance by any of the biofuels supplier.

(c) Indicative Targets for Carbon and Sustainability Criteria in the UK
The RFA (empowered by the UK Government) has set the following indicative targets for biofuels suppliers under the RTFO.

Table 4.1 Indicative Targets for Biofuels Suppliers

Annual target	2008/09	2009/10	2010/11
Percentage of feedstock meeting a qualifying environmental standard	30%	50%	80%
Annual average GHGs saving of biofuels supplied	40%	45%	50%
Data reporting on sustainability characteristics	50%	70%	90%

Source: RFA (2010a).

According to the recently published performance data (1 July 2010), the first nine months of the obligation period 2009/10 indicates some achievement of the targets. 34% of biofuels are estimated to have met a qualifying environmental standard, compared to the 50% government target. The ability of suppliers to source certifiably sustainable fuels is currently limited, as there are a number of feedstocks for which

117 The UK Government originally encouraged the use of biofuels through a duty differential for biodiesel and bioethanol of 20 pence/litre below regular fuel. For the first two years of the obligation, the buyout price was 15 pence/litre. It will rise to 30 pence/litre, once the fuel duty incentive is phased out in March 2010.

there is currently no operational sustainability assurance scheme. However, it is expected that certified sustainable feedstock should become increasingly available over time as feedstock standards are developing in response to the demand created by the RTFO. The data shows GHG savings of 51% were achieved against the Government target of 45%. Besides, 73% of the data captured from suppliers provided information on “carbon and sustainability” characteristics, compared to the 70% Government target.

The Climate Change Act (2008) assigns a new duty for the RFA to promote the supply of renewable fuel whose production, supply or use, contributes to the reduction of carbon emissions and to protect/enhance the environment in a sustainable manner. This duty came into force in January 2009, and recognises that the RFA has a role in encouraging transport fuel suppliers to supply green and sustainable (G&S) biofuels as guided by the Meta/Qualifying standards.

4.1.3 The UK Government Response to Systemic Risks

Two months after the implementation of the RTFO, biofuels' economic and social benefits have been questioned by international/local pressure groups. These questions arose because, the 1G biofuels deployment had created two systemic risks: the food-fuel competition and biodiversity threatened (refer appendix 7.3.1). These scenarios were further amplified by international/local broadcasting/print media.

Due to growing concerns about the sustainability of biofuels, the UK Government has commissioned Professor Ed Gallagher-the Chair of the RFA, to carry out a review of the evidence concerning the indirect impacts of biofuels. The Gallagher Review of the “Indirect Effects of Biofuels Production” was published in July 2008 (refer appendix 4.1.5). The report recommended that due to the risk of unintended indirect effects, the UK Government should reduce the rate of increase of targets for biofuels adoption.

Since the systemic risks have been highlighted by the international/nationl media and pressure groups, the UK Government has stepped in to slow down biofuels expansion by altering the RTFO targets. Based on BBC News dated on 7 July 2008, Ruth Kelly, the previous UK Secretary of Transport declared, that the UK Government had decided to slow down its biofuels adoption, admitted fears that biofuels deployment would raise food prices and harm the environment further. “We need to proceed cautiously until we can be certain that their expanded growth and use would maximise the benefits and minimise the risks to our world”, Kelly is reported to have said.

Meanwhile the King Review (2008) highlights, “In the longer term biofuels have the potential to make a significant contribution towards reducing emissions in the transport sector”, the UK Government decided not to terminate biofuels use, but respond to the Gallagher Review by slowing down the increasing rate of the RTFO targets. This change resulted in the Renewable Transport Fuel Obligations (Amendment) Order 2009 (SI 2009/843) with the revised obligation levels[118].

To protect the high biodiversity area, according to the House of Commons Environmental Audit Committee (2008), the UK Government has been working actively with other negotiating partners under the UN Climate talks, to develop a mechanism on the Reduction of Emissions from Deforestation and Degradation (REDD) in developing countries. Since 2005, the UK has committed £50 million to slow down the rate of deforestation in the Congo Basin. In Bali, the UK announced a contribution of £15m to the World Bank Forest Carbon Partnership Facility-a pilot programme designed to implement and evaluate a market-oriented incentive scheme for reducing deforestation rates in three to five developing countries, over a period of up to ten years.

118 3.25% for 2009/2010, 3.5% for 2010/2011, 4% for 2011/2012, 4.5% for 2012/2013 and 5% for 2013/2014 onwards.

4.2 The Scottish Government in Relations with the UK and the EU Government

Since the UK is one of the member states of the EU, most of the decisions made by the EU and the UK Governments, would have an impact on Scotland. Evidenced by the publication by the SG (2008a), over 70% of its national legislation is directly influenced by decisions taken at the EU level. Transport, energy, environment and others[119] are all policy areas in which the EU legislation directly affects the Scottish citizens. Although the EU affairs are reserved to the UK Government, Scotland must comply with the EU legislation incorporated into the UK Law in Reserved Areas. It is the SG's responsibility to implement the UK legislation into Scottish Law under the Reserved Matters, and to be the legislator for areas under the Devolved Matters (refer appendix 4.2.1).

Membership of the EU does not just mean that Scotland and its citizens must live by EU rules. The Union's aim to equalise the standard of living throughout all of the EU member states, has a significant impact on Scotland. In order to protect Scotland's interests, the nation's voice is presented by the SG and the Scottish Parliament from the outset of the EU/UK legislative process participations. The SG has it responsibility as an "executor" to implement the RTFO execution in Scotland. Supported by the Renewable Action Plan (RAP, 2009-refer appendix 4.2.2), the SG is continuing to engage closely with the UK Government on the scope of RTFO legislation and the financial incentives which they both have created.

4.2.1 The Scottish Government in the Next Generation Biofuels Development

The SG, under the leadership of the Scottish National Party has made it clear that, the SG main role is working towards a sustainable green economic growth (RAP, 2009). The internationally debated issues of climate change and GHG reductions have put much pressure on many countries' economic activities-which ultimately relate to the GHG emissions. Yet, these two issues are perceived by the SG, as an opportunity for

119 agriculture, economic and financial affairs, employment, social policy, the right to travel, communications.

its national economic transformation, to pursue the green economy (refer appendix 7.1.5) for RE generation and utilisation.

Scotland has its competitive advantage at natural resources and geographical setting. The hilly landscape, strong wind, high precipitation, powerful tidal/wave, vast area of lands, rich biomass from forest residues-which could be used as woodfuels and biofuels; all of these are the natural advantages for many sources of RE generation. According to the RAP (2009), the benefits for Scotland in exploiting RE generations are very significant, and the rewards for green economy are tangible. Jobs are created-linking science, engineering and business with an environmental focused.

Exportable RE technologies are being developed, ranging from fuel cells, biofuels, H_2, marine energy and offshore wind. Direct financial benefit is flowing into Scotland from the generation and sale of these RE technologies. This is evidenced by the speech made by Mr. Alex Salmond-the First Minister of Scotland who was quoted by the local media as saying: “Scotland has an abundance of clean renewable energy resources: wind, wave, offshore wind, tidal, biomass and biofuels. Scotland's renewable potential is immense, enough to meet our energy requirements many times over” (BBC, 7 September 2007; 16 February 2009).

The research points out, compared with the UK Government[120], the SG demonstrates a more progressive effort in the NGB development under the Devolved Matters. There are some pioneer works being undertaken, like the UK’s first biodiesel plant, and the UK’s first biofuels research centre which have been established, and there are other ongoing R&D projects which foster the NGB development in Scotland. The general roles of the SG in the NGB development are to provide leadership, coordination and communication with other industrial players. It is focused on

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120 The UK Government is keen on ultra-low carbon energy. In April 2009, the UK Government released “Ultra-Low Carbon Vehicles in the UK”, a document that sets out the UK’s ambition to become a world leader in the R&D and demonstration of ultra-low carbon vehicles. The document includes a road map depicting various developments for the next five years, ranging from pioneering projects of electricity and H_2, to illustrate the potential of these vehicles in a real world setting.

driving progress, ensuring business success, jobs growth and carbon reductions. It coordinates and facilitates the partnership working between the public (the EU/UK Government) and the private sectors.

As one of the three focus of the RAP (2009) under low carbon vehicles, the section considers the impacts of GHG/CO_2 emission from road transport to make better use of low carbon alternative fuels. The RAP (2009) sets that, by 2020, 10% of Scotland's transport fuels would come from RE. This is also tailored to match the EURED (2009) which have the similar 10% target for its member states by 2020.

Subsequently, a Consultation on Low Carbon Vehicle (CLCV, 2009) is published. As part of the transport contribution to reduced emissions, the SG intends to set an ambitious target for the use of alternative road fuels. The CLCV (2009) proposes the use of biofuels and H_2 powered vehicles[121]. It proposes a 100% use of alternative powered vehicles of public sector vehicles by 2020, combined with a Scottish national target of 30% for other road users. As part of this commitment, various incentives would be set for industry to develop the NGB in Scotland for road transport use. The CLCV (2009) reflects these ambitious targets which would be lead by the public sector in order to reduce emissions and to stimulate the Scottish economy through the NGB production.

4.2.2 Milestones of the Scottish Government in the Next Generation Biofuels Development

Apart from executing the RTFO in Scotland, there are works established or still being carried out by SG in the NGB development. According to the Policy Manager from the interview: “The Scottish Government has a very strong role in encouraging biofuels in Scotland. Our First Minister is very keen in the green economic development.” These completed/ongoing projects, demonstrate the SG's efforts in embarking on the NGB development.

121 which the fuels would be developed respectively. The SG concentrates on the NGB, while the UK Government focuses on the H_2.

(a) Established the UK’s First Biodiesel Plant, 2005

Argent Energy Limited (Argent) was benefitted from the SG and the EU Government financial injections. The plant acquired £15 million investment in total. £1.2 million was granted from the Regional Selective Assistance (RSA-refer appendix 4.2.3) which was supported by the Scottish Executive. A further £2.18 million was granted from the EU for research and operational use. The venture capital from Cinven provided the remaining investment in the company.

Argent is a waste-to-biodiesel business, operating a multi-feedstocks biodiesel plant near Motherwell in Scotland. The plant currently utilises animal fat/tallow and used cooking oil (UCO) from the catering industry as feedstock. Its production capacity achieves 45,000 tonnes of biodiesel a year or in excess of 50 million litres per annum. The company commenced production in March 2005, and is the first large scale producer of biodiesel in the UK (Argent Energy, 2008a).

As explained by the Argent Public Relations Consultant from the interview: “Our product (biodiesel) is renewable and clean, synthesised from organic oil-based materials. Currently we use animal tallow and UCO which are supplied from farms nearby, factories and restaurant chains. It (biodiesel) is non-toxic, biodegradable, can be blended with mineral diesel and used in normal diesel engines. From our research, biodiesel can deliver benefits to both the environment and to vehicle engines where it acts as a lubricant.”

The process technology used for biodiesel production (transesterification) was developed by Biodiesel International. This is an Austrian firm which collaborated with the Universities at Graz in Austria (Argent Energy, 2008b). According to Mittelbach and Gangl (2006), biodiesel is widely used in Austria. The city of Graz has its municipal bus fleet fuelled entirely by biodiesel. Therefore Argent has adopted the Austrian technology (through licensing) for its biodiesel production.

The researcher was advised by the Public Relations Consultant, that Argent's customers are Shell, Petroplus, Harvest Energy and Greenergy. They blend and distribute biofuels for the UK market. “Argent has supplied Petroplus 41.5 million litres of biodiesel since 2006. The product (neat biodiesel from Argent) is taken to Grangemouth and Teesside, blended with 95% diesel and marketed under the Petroplus's Bio-Plus brand,” said the Public Relations Consultant. Petroplus is a strong market leader which currently, it has 60% of the UK biodiesel market share (Argent Energy, 2006). “The Stagecoach West is also one of our customers. They have converted eight buses to operate on biodiesel. We are the sole supplier for this company,” added the Public Relations Consultant.

The Policy Manager went on to say: “The process of producing biodiesel (from Argent) has no risk from the materials or environment and has a longer lifecycle. In the sustainability term, that is an excellent example. Biofuels sources are waste products, being reused and recycled, and then put back into society. I have not seen any criticism about using animal tallow. This project is a track record for the Scottish Government in supporting sustainable renewable energy.”

Through using UCO and animal tallow as feedstocks in producing biodiesel, Argent's production technology hits three birds in one stone. Firstly, these feedstocks are cheaper compared with fresh vegetable oil, because they are unwanted industrial/agriculture by-products. By reusing/recycling and turning them into biofuels, Argent has reduced wastes significantly and attained economies of scale. Secondly, these feedstocks are sustainable, as they neither impact on biodiversity nor create food-fuel competitions like the 1G biofuels does. Since animal tallow and UCO would only be sent to landfill, by reusing/recycling them, Argent has created an added value on these wastes. Thirdly, Argent's waste-to-biodiesel production is well known among its peers. Thus, this business is sustainable for Argent, which consequently allows Argent to gain a higher recognition within the industry. Supported by Booth, et al., (2005), the use of UCO/tallow as feedstocks, provide a competitive advantage for Argent as these resources would not compete for other feedstocks.

Research supported by the Life Cycle Analysis [122] conducted by the Technical University of Graz: in 2008, found that biodiesel from tallow and UCO is better for the environment than biodiesel produced from virgin oils such as rapeseed oil. Taking into account all the energy used in producing biodiesel from tallow and UCO, and adding the displacement of CO_2, Argent's production activities have a net positive effect on the environment (Argent Energy, 2008a).

Argent plans to have more UCO collected from households and businesses through the local council recycling schemes. A visit to Argent plant by Stewart Stevenson-the Scottish Minister for Transport, Infrastructure and Climate Change has opened up an opportunity. This is because, too much of the used oil from homes and restaurants ends up going down the drain or into bins. In Austria, recycling domestic UCO is as commonplace as recycling paper, cardboards and glass in the UK. Jim Walker-Managing Director of Argent commented: "We would like to see more domestic collection facilities established, and to stop households and businesses clogging up our drains with waste oil and fat. The government can provide a lead by working with councils to achieve this" (Argent Energy, 10 March 2009).

In fact, the suggestion to the Scottish Minister was not a new idea. It was rather an extension of the previous partnership built between Argent and Stagecoach. Since October 2007, Argent has been involved in a mutually-beneficial-partnership whereby Stagecoach (a Scottish-based bus and coach operator) encourages its passengers to recycle their domestic UCO through East Ayrshire Council in return for discounted bus travel. Argent then turned the UCO collected into biodiesel which is used to fuel some of Stagecoach buses.

If the UCO local council recycling scheme could be materialised, then Argent could

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122 The Life Cycle Analysis is aimed at assessing the environmental impact of Argent Energy's production of biodiesel from UCO and tallow. It takes into account all the energy used in producing biodiesel from these materials and the displacement of CO_2. The data generated describes the ecological footprint of biodiesel from these sources compared to mineral diesel (Argent Energy, 2008b).

use more locally sourced UCO, and benefit from lower production costs. Walker explained: “Currently much of the used cooking oil we process comes from south of the border. We want to develop our capability to use more locally sourced used cooking oil, and so to reduce the distance our raw material has to travel. Apart from profits, we also want to do more to achieve a cleaner and greener Scotland” (Argent Energy, 10 March 2009).

A year later, Argent won the award of “The Most Sustainable Biodiesel Producer in the World”, beating off large competitors like Nestle Oil and Mabanaft (World Biofuels Markets, 17 March 2009). Through Argent's newsletter (17 March 2009), Walker said: “We have been able to demonstrate that high quality biodiesel can be made sustainably by recycling by-products of other industries. We are delighted to bring the award for Sustainable Biodiesel Producer 2009 home to Scotland where we have received so much support and encouragement.”

Talking about future plans, the Public Relations Consultant stated: “We plan to have our second plant at Ellesmere Port in Cheshire in 2011 to 2012. This plant is planned to have an annual production of 170 million litres, which is three times more than the capacity of the existing plant. It is expected to be built in two stages. The first phase will provide 85 million litres of production capacity, and the infrastructure to double that as the market develops. Our objective is to be a leading biodiesel producer from waste-to-product production. Most of the producers are still using fresh vegetable oil. We want to achieve this through investment in feedstock research and our production capacity.”

(b) Setting up the INEOS Biodiesel Plant, 2006-Currently on hold due to Financial Crisis

Information was obtained through the interview with the Policy Manager, where she mentioned another biofuels plant construction project was on-going, yet she did not have the latest information on hand. Sought the news releases through the SG website on 17 October 2006, Europe's largest biodiesel production plant was planned to be built at Grangemouth in Scotland with funding support from the Scottish Executive. The investment has been backed by £9 million from the RSA Scheme, while INEOS Enterprises has invested £70 million in the production facility-which would supply around 35% of the UK's biodiesel needs.

The aims for this plant would achieve three benefits. Firstly, it was aimed to place Scotland as the leader in large volume production of biodiesel. Secondly, the production not only could generate adequate supplies of biofuels needed for the UK (under the RTFO), but also could fulfil the EU on regional biofuels demand. Thirdly, the plant could provide more job opportunities for the local workforce in Grangemouth-which was the main criterion specified by the scheme for employment creations. This was supported by the speech made by the Deputy First Minister Nicol Stephen: “The Grangemouth facility will be the largest biodiesel plant in Europe, and will supply around a quarter of the UK's total biofuels needs by 2010. The RSA £9 million is the largest we have ever made to a renewable energy project. This is a good news for the workforce in Grangemouth, a good news for our clean energy ambitious and a good news for Scotland's wider business growth potential” (The Scottish Government, 17 October 2006).

Grangemouth is the centre of Scotland's petrochemical plants and crude oil refineries. Some of the world’s biggest oil players like Conoco Philips, Shell, BP and ExxonMobil could be found here. The hub plays a significant role in supplying refined oil and gas products to Scotland, Northern England and Northern Ireland. The researcher has been informed by the Policy Manager during the interview that, INEOS owned the Grangemouth refineries since 2005, after taken over from BP. Therefore this justifies INEOS’s ambitious to have its biodiesel plant at Grangemouth.

Since the construction of biodiesel plant started in October 2006, the plant should start production in 2008 as planned. Unfortunately, further information obtained through the BBC News (27 November 2008)-the project has been on-hold due to the current economic slowdown. The project would continue, but no further information has provided. The INEOS spokesman commented: “Plans to invest are on-hold until INEOS has a clearer picture of the economic outlook”. Additionally, Councillor Craig Martin-Convener of Falkirk Council's Economic Development Committee responded: “We are disappointed that this innovative idea isn't going ahead. However, we are willing to assist INEOS, particularly when it comes to preserving jobs.” Regrettably, at the end of 2011, there is still no news about this ambitious project.

(c) Established the UK’s First Biofuels Research Centre, 2007

The Policy Manager from the interview explained: “The Scottish Government has funded £500,000 as research funding to the UK first biofuels research centre in Napier University-named as the Biofuels Research Centre (BfRC) since December 2007.” According to the Napier University's newsletter (11 December 2007), the BfRC is led by Dr. Martin Tangney who is committed to R&D the 2G biofuels from a potentially diverse range of non-food crops and waste matter. The BfRC is acting as a portal between industry, government, academia and the public.

From the same newsletter, Jim Mathers-Minister for Enterprise, Energy and Tourism at the SG said: “We are exploring how we can best exploit technologies to make a real, sustainable and cost-effective contribution to tackling climate change, including the role of biofuels.” Professor Joan Stringer-Principal and Vice Chancellor of Napier University responded: “Sustainability is a hugely relevant issue and is one of Napier’s highest priorities. The opening of this centre not only shows our commitment to this, but also our dedication to lead new areas of research.”

The £500,000 research funding showed the eagerness of the SG in advancing the 2G biofuels. Pachauri (2006) explains, a government has a responsibility for fostering R&D. Adequate funding should be made available for this purpose, as well as for demonstration projects covering various aspects of biofuels development. Apart from playing a role as funder, the SG also monitors the progress of the BfRC. The collaboration between the SG and the BfRC, ensures the continuous political support by way of financial funding can contribute to successful research outcomes.

After more than two years of research, the BfRC has finally tapped into the whisky industry to create biobutanol. According to the Scottish Enterprise webpage (17 August 2010), the BfRC has filed a patent for biobutanol-which can be used in ordinary cars. An additional £260,000 research project has been funded by the Scottish Enterprise. The BfRC is working with the country's whisky producers by using two types of whisky by-products "pot ale"[123] and "draff"[124].

Tangney commented: "Using whisky by-products to develop biobutanol is a more environmentally sustainable option, and potentially offers new revenue on one of the Scotland's biggest industries". Lena Wilson, CEO of the Scottish Enterprise responded: "This research demonstrates how Scottish Enterprise helps to transform cutting-edge knowledge into successful high-growth sustainable businesses for Scotland". Besides, Mather said: "The Scottish Government supports the development and the use of sustainable biofuels. This innovative use of waste products is supporting the economic and environmental objectives of the Scottish Government's new Zero Waste Plan." Meanwhile, Susan Morrison-Director and General Manager at The Scotch Whisky Experience said: "Working in a tourism role to represent the Whisky Industry, the green agenda is moving forward at such a pace, both through the Green Tourism Scheme and innovations as this new whisky biofuels" (Scottish Enterprise, 17 August 2010).

With 1,600 million litres of pot ale and 187,000 tonnes of draff produced by the malt whisky industry annually, these by-products set real potential for sustainable biobutanol production. Putting an added value on the industrial waste in order to

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123 the liquid from the copper stills. It is a residue left in the washed still after distillation. It is previously sold and used as liquid fertiliser or dried cattle food (Feeds Marketing, 2010).
124 the spent grains, as the basis for producing the biobutanol. It is the residue which remains after the liquid "wort" (malted barley in hot water) is drained off to be fermented and distilled as alcohol. Nutritionally, draff is rich in digestible fibre and also contains concentrated protein and oil from the malted barley. It is moist and palatable to all types of ruminant stock (Feeds Marketing, 2010).

materialise the reuse-and-recycle, the SG is one step closer to prove the zero waste plan and green biofuels production is applicable.

(d) £600,000 to Fund Scottish Crop Research Institute to Involve in the University Dundee for the Next Generation Biofuels Development, 2009

According to the University of Dundee's (UoD) newsletter (27 January 2009), funded by the UK Biotechnology and Biological Sciences Research Council (BBSRC-refer appendix 4.2.4), the £27M Sustainable Bioenergy Centre (SBC-refer appendix 4.2.5) is established to research and develop the NGB.

The Minister of State for Science and Innovation-Lord Drayson, said: “Investing £27 million in this new centre involves the single biggest the UK public investment in bioenergy research. The centre is leading the way in transforming the potential of sustainable biofuels”. The BBSRC Chief Executive-Professor Douglas Kell said: “The SBC draws together scientists from six universities to develop technology which supports the sustainable bioenergy sector. The Centre is examining all the relevant areas of science needed for sustainable bioenergy. Working closely with industrial partners, the Centre’s scientists will be able to translate their progress into practical solutions” (UoD, 2009).

This information was first revealed by the Executive from the Rural Directorate during the interview: “The Scottish Government is setting a fund in conjunction with the Scottish Crop Research Institute (SCRI) to produce biofuels which is led by the University of Dundee.” The UoD has been named as one of the six research hubs (refer appendix 4.2.6). It is working with University of York and two Scottish public partners-the SCRI and the Rural and Environment Research and Analysis Directorate (RERAD). The Dundee-led programme is concentrating on improving barley straw for lignin properties, altering them to make it easier for biofuels production. Under this collaboration, the SG is contributing £600,000 as additional investment, over the next three years to fund the SCRI’s involvement in this programme.

According to Professor Claire Halpin-Head of the College of Life Sciences the UoD:

“If we can find a way of accessing these key sugars in barley straw, it would have a significant impact on the types of agricultural waste, and dedicated energy crops that could be used to produce sustainable biofuels.” Peter Gregor-Chief Executive and Institute Director of SCRI said. “The programme will help for a significant change in energy use, leading to a secure future for both energy provision and food production” (UoD, 2009).

The Executive of the Rural Directorate from the interview added: “This programme uses barley straw because the SCRI has done a few projects on barley straw research. They were very basic, to understand its biological structure. Now, this new programme (led by the UoD) can extend the previous works and making it commercially viable.”

This series of research programmes which are funded by the BBSRC has created a strong interlinked between academic and industrial. Apart from research jobs creation, one of the most significant benefits from such collaboration is the innovative knowledge transfer between both sectors. The research institutions gain access into industrial resources, knowledge and networking. Meanwhile the industries obtain the advanced knowledge of their field. For the oil companies (BP and Shell) that have their own the NGB R&D projects, the new collaboration under this scheme would complement their ongoing industrial R&D. By pooling in the research capability of the academic/research institutions, while assisted by the industrial players; the potential research outcomes would become the assets for potential commercialisation.

(e) Launching the 3G Biofuels (Biomara) Project, 2009

Led by the Executive of Renewables Policy Team from the interview: “There is one algae biofuels happening in Oban, Scotland.” This information was not publicly available until June 2009. The project was then officially stated in the RAP (2009) as the Biomara project.

The Scottish Association for Marine Science (SAMS) and its partners have secured nearly €5 million from the EU's INTERREG IVA Programme for this project. The Biomara is a UK-Irish-joint-project which aims to demonstrate the feasibility/viability of producing the 3G biofuels from microalgae. This major research initiative is led by the SAMS but involves inputs from a number of partners from Ireland and Northern Ireland[125].

4.2.3 Promoting the Next Generation Biofuels through Organisational Media

Since the emergence of the two systemic risks resulting from the 1G biofuels deployment, the UK/Scottish Governments are working towards seeding public confidence in the NGB. Three channels of communication have been utilised: print, broadcasting and internet media[126] to promote any political decision/information about the NGB development to the public (refer appendix 4.2.7).

The SG utilises its own website the most to disseminate information to the public. The SG's website has a collection of images, videos, documents and archives-like policies which provide the full-text publications that are downloadable free of charge. This information is constantly being updated to show the latest development. The website is user friendly, allowing keyword string searches.

Generally, the SG's website is a one-way information broadcaster. It allows the users to access/gain further information from the website, but does not allow users to comment on the page. However, the user is still able to leave any comments through email sent to the webmaster, or to fill in an electronic form with comments attached then submit to the webmaster. The SG also produces print publications of their policies that are available to be purchased from Blackwell's Bookshop.

Meanwhile, the broadcasting/print media are not under the SG's control. These external media are disseminating the SG’s messages about biofuels from time to

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125 Dundalk Institute of Technology, the University of Ulster, Queen's University Belfast, Dublin City University and Sligo Institute of Technology.

126 print media: newspapers, internal print publication like policies; broadcasting media: radio, television; internet media: website, YouTube.

time. The Executive of Corporate Service Team from the interview explained: “The Communication Directorate is the “mouth” of the government in disseminating information, “eyes” in monitoring the external media and “hands” in setting up the internal media (the SG's website and print publications). We have to monitor the external media, making sure they say what we want to say, to keep messages exact, accurate, short and concise. So that the media cannot take and choose; just pick one part of the message or manipulate our message. We also supervise the messages provided to the media. Some of our press officers are reading newspaper every day, watching and checking news. This is media supervision, making sure they (the external media) say what we want to say.”

4.3 Conclusion

The EUBD (2003) laid a clear direction for the regional biofuels adoption until 2010. This was then extended by the EURED (2009), which prolongs biofuels as one of the RE profiles to constitute a 10% share for the future transport by 2020. Both of the regional policies were then transposed into the UK RTFO (2008). The RTFO was commenced on 15 April 2008, places an obligation on fuel suppliers, that road fuels supply in the UK must comprise of biofuels according to the annually-increasing-targets specified. The RTFO is expected to continue beyond year 2020.

Since biofuels implementation in Scotland is influenced by the EU/UK Government, the SG plays its role as the biofuels executor in Scotland. Under the RTFO, the UK Government has a higher authority on biofuels implementation and of the related decisions. Biofuels deployment in the UK is promoted by fuel duty incentives to keep the overall costs effective. Different media was used to promote the benefits of biofuels adoption, helped to create social acceptance of biofuels. Warranties provided by automobile manufacturers are one of the most influential strategies which boosted social confidence on biofuels use in their existing ICEs.

To control the biofuels suppliers, the RFA was established. The RFA manages and controls suppliers through the RTF certificates. Furthermore, the RFA requires biofuels suppliers to comply with the “Carbon and Sustainability” monthly reporting system. Apart from the annual targets, the G&S of biofuels product and production are gradually emphasised, to make sure the biofuels suppliers/oil companies comply with both the quantity and the quality of biofuels supplied in the UK. In addition, European Biofuels Standards are adopted, to create the standards of unification among regional member states that would foster the regional trade.

After two-three months of the RTFO execution, two systemic risks occurred have challenged the economic believes and social benefits of biofuels. The situation was further amplified by the pressure groups as well as the social media. The UK Government appointed Professor Gallagher to conduct a review. His conclusion suggested that biofuels could continue provided the rate of expansion is slowed down. Subsequently, the RTFO targets have been altered. The G&S biofuels criteria have also been stringent by the Meta/Qualifying standards, as well as the Indicative Targets for Carbon and Sustainability Criteria (2010). These criteria are encouraging the existing biofuels suppliers/oil companies to select biofuels that are G&S. To rebuild public acceptance of biofuels, the NGB which portrays more G&S criteria is promoted through their organisational (the regulators and the oil companies) media.

Working under the Devolved Matters, the SG shows its affinity on the NGB development. Numerous the NGB projects are executed and established by the SG. The Argent waste-to-product for the NGB biofuels and the Napier University whiskey by products-to-biobutanol are two examples which made Scotland gained it reputation internationally as one of the leading G&S biofuels producing country. Additionally, there are a few on going the NGB R&D projects such as the 2G biomass biofuels and the 3G algae biofuels. The pursuance of the NGB development clearly signifies that, the SG's vision in RE generation, and working towards a sustainable green economic growth.

Chapter 5 BP in Biofuels Business

Preface

As one of the world's six oil companies which is engaging on the next generation biofuels (NGB) development (refer appendix 7.1.1), BP is currently supplying biofuels in the UK under the Renewable Transport Fuel Obligation (RTFO). This chapter presents the rationales which stimulated the business interests of BP, to embark on the route of pursuing biofuels supply and innovation. Operating under the regulated market, the EU/UK Governments have established mechanisms which help to deliver biofuels deployment and development regionally/nationally. This study has provided an insight into the interactions generated between BP and the EU/UK Government, whilst examining BP's response to the mechanism instituted. Since any technological change is a dynamic process, which incurs various types of expected/unexpected risk and uncertainty (R&U), this chapter also describes how BP has coped/strategised to deal with the R&U arose during biofuels deployment and development.

5.1 Introduction

Founded in 1908, with the headquarters located at the City of Westminster London; BP is one of the largest global conglomerates, has been supplying fossil energy products for more than a century. Operating in more than one hundred countries, BP's expertises cover three areas: exploration and production; refining and marketing; and alternative energy introduction and development (refer appendix 5.1.1).

In 2005, BP started its biofuels business-operating as one of the biofuels distributors in the US under the US Renewable Fuel Standard (RFS) 2005 (refer appendix 5.1.2). The home-grown maize and soy backed the biofuels production and supply. BP started supplying biofuels in the UK from 15 April 2008 under the RTFO. Until 31/12/2011, BP still does not manufacture biofuels. Instead, BP buys them on the international market-mainly from Argentina, US, Brazil and blends these biofuels with conventional fuels before supplying them into the UK. It is expected that, the undergoing NGB R&D projects will be able to produce green and sustainable (G&S)

biofuels at commercial scale within five-to-ten years from 2008.

5.1.1 Three Driving Forces for BP Biofuels Uptakes

In 2007, BP blended 763 million US gallons of bioethanol and 1million US gallons of biodiesel in the US, which constituted approximately 10% of the global market (BP, 2008a). The blend is made in the US, mainly due to the availability of the home-grown feedstocks: soy and maze; and also the manufacturing facilities[127]. The US not only can produce enough biofuels to satisfy its domestic demand, but also produce a surplus for exporting purpose. In 2008, BP blended and distributed more than one billion US gallons bioethanol and around 1.6 million US gallons biodiesel, which was partly exported to the UK for the RTFO. The message from this data is clear: demand for biofuels has increased dramatically from the growing international market including the member states of the EU, after the adoption of the EU Biofuels Directive (EUBD) 2003.

"There are three drivers: energy security, environmental concern and prospering agricultural industry, all of which are pushing biofuels up for the agenda," explained Philip New, CEO of BP Biofuels (BP, 2007a). These driving forces are shaping biofuels as one of the core business areas since 2007 (Knott, 2007).

(a) Towards Energy Security

Global energy demand looks set to increase at least 50% over the next twenty years. Currently, around 55% of the world's crude oil is converted into transport fuels (BP, 2007a). However, many countries are highly dependent on importing oil to mechanise their economy. The Fuel Engineer from the interview commented: "It was a key concern during the big swings in energy markets for the past few years. This is driven by population growth, and rapid industrialisation in the developing economies

127 The US is the world's largest producer and exporter of corn. The US share of world corn exports averaged at 60% during 2003-2008, which recorded 61 million metric tons in 2007/2008[1]. Besides, the US is also the world's largest soybean producer and exporters, accounted 90% of the US total oilseed production[2].
Source[1]: United States Department of Agriculture. 18 February 2009.
Source[2]: United States Department of Agriculture. 8 December 2008.

like China and India." The global supply of fossil fuels is already consolidating, with 70% of the world's oil now sourced from just six countries, and 50% of natural gas produced in just three (BP, 2009b).

According to Tony Hayward, the BP Group Chief Executive: "Energy security remains at the top of the global political and economic agenda. The need to balance energy security and economic development, while addressing the problem of climate change; all have contributed to the challenges that our politicians faced" (BP, 4 February 2010). Therefore, governments particularly those in the Organisation for Economic Cooperation and Development (OECD) are striving to become less dependent on imported oil/gas, and are seeking alternative sources of supply.

From the interview, the Fuel Engineer added: "Biofuels derived from plants, offer a partial solution that can be achieved in the relatively near term. At least biofuels can form a small portion for transport fuel components in powering road transport." Hence, the growing plans for producing biofuels locally or in the non-oil producing nations could ensure a more secure supply of transport energy (Knott, 2007).

(b) Environmental Concern in Combating Climate Change

The total number of vehicles moving on roads around the world is predicted to pass the two billion mark by 2050. Whilst climate change and energy security concerns are already bringing forward changes in the way vehicles are powered, the internal combustion engines (ICEs) fuelled by petrol/diesel/liquefied natural gas (LNG) are still expected to be remained as the dominant fuels for transport (BP, 2008b).

As supported by scientific evidence, biofuels emit less CO_2 into the atmosphere compared to conventional hydrocarbon-which account for 15% of total global emissions (Fuglestvedt, et al. 2008). This is further strengthned by biofuels' carbon neutrality-from growing to burning in the fuel tanks which could achieve near carbon neutrality, if the land use and production activities (refer appendix 5.1.3) are fully integrated to minimise the CO_2 release.

(c) Prospering Agricultural Industry

Many governments want to see their agricultural communities become more prosperous. The prospect of biofuels with increasing global demand offers a promising opportunity to the agriculture sector. According to New: “The emergence of a biofuels industry involves the coming together of two major value chains for the first time: the agriculture and energy. Both are mature and sophisticated industries with connections to national politics” (BP, 2007a). Thus, developing countries, such as India, Brazil, South Africa and South East Asia have opened their doors, and welcomed business opportunities from BP to invest in biofuels feedstocks farming.

5.1.2 The UK Government's Interests in Biofuels

These three drivers mentioned above, are identified as the generic forces in justifying biofuels development and deployment from BP's perspectives. From the interview, the Sustainability Strategy Manager commented: “When you look at the broader picture, biofuels stand out as the option that has the potential to help address of these concerns.”

BP has been working with worldwide national governments. However, not every government is sharing the same three drivers equally. Supported by the interview: “The UK takes a very interesting approach on biofuels. In biofuels there are three main categories. You have those pursuing climate change, greenhouse gases reduction; those pursuing rural development or farming for farmers and land; and those pursuing energy security by reducing their dependency on oil. An example of pursuing energy security would be the US. The examples in pursuing rural development are Poland and the US; and an example pursuing climate change in emphasising greenhouse gases reduction is the UK,” said the Sustainability Strategy Manager.

The research investigated further the other two driving forces (prospering agriculture and energy security), to find out the reasons why they have not been the main factor driving the update of biofuels in the UK. Firstly, due to the climate and the availability of lands, agriculture activities are rather restricted in the UK. There are nine main types [128] of crops commercially farmed in the UK. They are being produced at a medium scale, which does not generate an absolute advantage for the UK. Consequently, food is still imported to fill up the gaps of demand. According to a report from the Department for Environment, Food and Rural Affairs (Defra) 2009: in 2008, the UK total crop output ranked in 8^{th} place among the EU27 member states. This shows that the agricultural sector is one of the GDP contributors in the UK, yet still not sufficient for its domestic consumptions.

Secondly, according to the Executive of North Western Europe Exchange Project (NWEEP) from the interview, due to the availability of oil and natural gas in the North Sea, the UK is one of the five nations[129] that has the economic exclusive rights to these natural resource exploitations. As such, energy security is not the highest priority for the UK Government at this current stage. Therefore, the UK is prone to the environmental concern towards CO_2/GHG reductions, which not only reflected from the interviews, but also (this message) appeares across the UK/Scottish climate change and related transport/biofuels policies.

5.1.3 BP Dealing with the EU/UK Governments' Policies and Regulations

BP is involved in the ongoing biofuels policy debate and formulation, by communicating directly with the EU/UK Government in promoting the need for sustainability standards. Besides, BP is closely involved with other bodies including the European Committee for Standardisation (CEN) (refer appendix 5.1.4) and the UK Low CVP Partnership (refer appendix 5.1.5) (BP, 2009c). Supported by the interview: “Working with policy makers, is not only can help the governments to meet emissions targets, but also can provide a more defined characteristic required for a sustainable biofuels business,” said the Executive of NWEEP.

Furthermore, BP supports the sustainable growth of the biofuels industry, as it helps address the challenges of energy security and climate change which have been

128 wheat, barley, oilseed rape, sugar beet, potatoes, oats, peas, beans and grain maize (The UK Agriculture, 2009).
129 the UK, Norway, Denmark, Germany and the Netherlands.

stressed globally as major driving forces of biofuels. As transport fuels demand is estimated to grow by over 55% by 2030, the EU/UK Governments are increasingly setting higher annual targets for biofuels use. BP foresees biofuels could represent up to 25% of the fuel pool by 2030 versus only 2% of world consumption in 2008 (BP, 2009d). From the interview: "Once you know the legislation is clear to support (biofuels), we will move to targets like 10% (EURED year 2020 specification) over the next few years. However the current debate continues, whether the substantial increase in biofuels' targets, these feedstocks can be grown domestically in the UK, or will have to be imported," explained the Sustainability Strategy Manager.

In the UK, due to the scarcity of suitable land for farming (in other word, the UK land is far more expensive for agriculture activities), plus the climate which is not ideal for feedstocks growing, the UK is a large importer of biofuels under the RTFO. From 15 April 2010-14 July 2010, the UK produced 12% biodiesel and 24% bioethanol for its domestic market. Argentina contributed 34%, Germany 15% and the US 11% biodiesel to the UK[130], while Brazil contributed 30%, France 14% and US 12% bioethanol[131] to the UK (RFA, 2010).

The UK demands a large volume of imported biofuels for its RTFO. Thus, the UK Government has been cautiously concerned with the source of the biofuels, the country of origin, the types of feedstock and land used. All of this information is important for the Renewable Fuel Agency (RFA) records. This is because, since the UK is consuming biofuels for the sake of national transport CO_2/GHG reductions (internally), the UK Government is obliged not to cause the environmental degradation on the biofuels exporting countries. It is clear that, the oil companies operating in the UK (supplying biofuels) are controlled by the RFA's regulation, which emphasis the requirement for social responsibility and environment

130 Proportion of biodiesel used under the RTFO by country-Argentina 34%, Germany 15%, US 11%, the Netherlands 8%, Indonesia 3%, France 2%, Malaysia 2%, Denmark 1% and Poland 1% (RFA, 2010).
131 Proportion of bioethanol used under the RTFO by country-Brazil 30%, France 14%, US 12%, and Spain 6% (RFA, 2010).

conservation. Biofuels which could not demonstrate the G&S criteria; in other words, violate or fail to comply to both the Meta/Qualifying standards outlined, will not only cause the biofuels supply business to be terminated (as the RTF Certificate will not be granted), but also will leave a bad public impression on the oil company who had its business ended.

Therefore for the sake of the continuation in biofuels business and profit seeking, these oil companies must obey "the rules of the game"[132]. The UK Government established the RFA, to monitor/control the domestic biofuels supply. The RFA has specified clearly the biofuels criteria required to be used under the RTFO through the establishment of the Meta/Qualifying standards. From the interview, neither Shell nor BP representatives made any negative statements about the RFA requirements. Both companies are complying strictly with the regulations set, in order to ensure that their biofuels businesses could be continued/sustained in the UK.

Financially, the UK Government had been supportive before the commencement of the RTFO. According to the report from the Department for Transport, DfT (2008), biodiesel and bioethanol are taxed at 20p/litre less than fossil petrol and diesel. This support is guaranteed until March 2010 to ensure the supply of biofuels is cost effective. The biodiesel incentive has been in place since July 2002, while bioethanol's since January 2005. According to the Executive of Renewable Policy Team (the Scottish Government) from the interview, the RTFO will continue "at least" until year 2020. This provides crucial confidence to the oil companies for the NGB investments.

As written in the BP corporate report (February 2007), the policy makers have been proactive in taking steps to support the industry for biofuels supply. The tax incentives and clear regulatory framework enable the oil companies to deploy and develop biofuels with confidence. To summarise the interactions between BP and the

132 Supplying biofuels which could demonstrate the G&S criteria, comply to the Meta/Qualifying standards, comply to the European biofuels quality standards, follow the RTFO mandatory targets, and reporting to the RFA on monthly "Carbon and Sustainability" reporting system.

EU/UK Governments: “We are the first global energy company to call for action publicly over climate change. We continue to strive for energy efficiency in our operations. We are investing in low-carbon energy as well as engaging with governments and regulators (international level) to shape legislation that will facilitate progress towards a low-carbon economy and make it commercially viable,” stated Hayward (BP, 1 April 2009).

5.1.4 Biofuels are Opted as one of the Renewable Energy for Transport in the UK

It has been nearly a century where petrol/diesel has been entrenched as the dominant world transport fuels. In the sphere of Renewable Energy for Transport (REfT), there are some possible options such as hydrogen (H_2)/electricity, which have been suggested before the decision was made on biofuels. Thus, it is interesting to know why biofuels have been chosen as the front runner.

As explained by the Fuel Engineer from the interview: “Hydrogen has been under a series of intensive R&D since 2000. We heard a lot about it, yet it is still hardly to be produced on a commercial scale. This is because it (H_2) does not comply with the criteria of efficiency at the principle of the first thermodynamic law. I don't understand why we would want to complicate the transport system, when there are easier routes (like biofuels). The entire fuelling system has to be changed if we use hydrogen.”

“Currently hydrogen could be produced through water electrolysis in a small to medium scale. To produce hydrogen in a great scale, petroleum extraction via chemical path or thermolysis is the way. In the energy system, it (H_2) is not an energy source, but an intermediate medium for storing and carrying energy. In other words, hydrogen only could be produced when energy is provided. Two units of electric energy are required to produce one unit of hydrogen energy,” explained the Fuel Engineer.

From an economic logic, the production cost and the switching cost of the H_2 based technologies are tremendously high. This is further supported by Hayward: “Electric vehicles and hydrogen fuel cells will have a part to play in the long term. But they need massive new infrastructure, and they need to be produced more sustainably” (BP, 4 February 2010). Thus, the exceedingly high costs have put off further investments from most of the oil/automobile companies. Furthermore, extracting H_2 from water will need energy as an input. By extracting H_2 from petroleum will lead the problem back to square one: generating energy from a depleting and polluting source, which neither help in combating climate change nor for energy preservation.

Backed by the interview: “Currently, the electric car is also facing the same problem (as H_2 does), due to the limited infrastructures such as the electric charging points. You can't find them everywhere in the UK, apart from London and some big cities like Birmingham and Manchester. The technical supports and the expensive electric car itself; all have caused to low adoption. Besides it also being questioned where the source of electricity is from. Either from fossil fuels or renewables, would make a tremendous difference in GHG reductions. If, the electricity is again, sourced from fossil fuel (to power electric cars), we will back to square one, there will be no significant GHG reductions,” commented the Sustainability Strategy Manager.

With the technical limitations of H_2 and electricity, and the technical convenience provided by biofuels, it is clear that biofuels with lower switching cost and their compatibility with the existing hydrocarbon infrastructures[133] are the factors which determined their front position. Besides, according to Steve Koonin the BP Chief Scientist: “It is no coincidence that biofuels are currently in the spotlight for transport energy. If you consider that all of life is based on carbon, and so too is 90% of the world's energy, there are bound to be synergies between biology and energy waiting to be discovered. Furthermore, the main pursuit for modern biological research, until now has been in the sphere of medicine. This means the field of energy bioscience is

133 for both supplying infrastructure, as well as adaptability in the existing internal combustion engine (ICE) vehicles.

largely an open territory. Fostering the intersection of biology with energy is therefore likely to generate technologies that can benefit the energy industry” (Knott, 2007).

5.1.5 BP Embarking on the Next Generation Biofuels Development

During the early commencement of the RTFO in 2008-2010, BP has not produced any biofuels for the UK supply. Currently, BP is buying biofuels from the international market, then blending and supplying for the UK market. There are three objectives which lead BP to embark on the NGB development (BP, 2009e):

(a) produce biofuels from the most efficient[134] feedstocks available today, while pushing for higher standards that bring cleaner, sustainably produced biofuels into the market,

(b) invest in new feedstocks, including cellulosic biofuels made from energy grasses, that have minimal impact on food supplies and environment,

(c) develop technologies to create advanced biofuels with higher energy content and greater environmental benefits[135].

As such, BP's biofuels strategy signifies that BP invests in the NGB R&D projects that can achieve tangible reductions in GHG emissions; can make a positive difference to energy security; and can offer commercial opportunities for the agriculture industry in growing biofuels feedstocks (BP, 2009f).

Further from two interviews: “Today, biofuels are a strong start. To achieve 20-30% of market penetration, new technologies (NGB) need to be developed,” said the Fuel Engineer.” “Since 2006, BP has invested more than USD1.5 billion in biofuels R&D and operations. This includes partnerships with other companies to develop the technologies, feedstocks and processes,” mentioned the Executive of NWEEP. BP is

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134 highest output with lowest costs

135 Non-food, low carbon/GHG emissions, low energy inputs, not polluting (no air/water/land pollutions by minimise agrochemical/fertiliser use), not pressure on high biodiversity areas, low water footprint, do not cause adverse land change but could be grown on marginal land.

forming partnerships with biotechnology laboratories, academic institutions and agricultural industry to develop the advanced NGB (BP, 2009g). These partnerships are ranging from direct funding, equity joint-venture (JV) and strategic alliance (SA) collaborations.

5.2 BP's Ten Next Generation Biofuels Development Projects

Since from year 2003 (to 2010), through three main partnerships (direct funding, JV and SA), BP has established ten NGB R&D projects (refer table 5.1 and appendix 5.2) which are spreading around the world. These projects set ways:

(a) to increase the productivity of biofuels supply for the aim of economies of scale,

(b) to switch biofuels away from the food chain,

(c) to overcome the limitations of the 1G biofuels,

(d) to emphasis the G&S criteria and to comply with regulations required by the EU/UK Governments (BP, 2009a).

Table 5.1: BP's Milestones

Year	Projects Partnership	Modes of Collaboration	Projects Information	Project Types
February 2006	BP and TERI	Funding	Planting Jatropha in Indian States of Andhar Pradesh. Jatropha is the 2G feedstock for biodiesel.	Feedstock plantation
2003, extended to 2006	BP and DuPont	JV	Biobutanol's R&D	Biofuels innovation
February 2007	BP and Energy Bioscience Institute (EBI)	Funding (in-house)	R&D on the NGB and other biotech-energy related projects	Biofuels innovation
June 2007	BP and Mendel	SA	Application of genomics for high yield feedstocks	Biofuels innovation
June 2007	BP, British Sugar and DuPont	JV	Producing Vivergo fuels (biobutanol)	Investing in production plant
June 2007	BP and D1 Oil	JV	Planting Jatropha in large scale as biodiesel feedstock	Feedstock plantation
November 2007	BP and Arizona State University	Funding	Photosynthesis bacterium to produce biodiesel (4G biodiesel)	Biofuels innovation
2008	BP and Tropical Bioenergia	JV	Setting up refineries producing bioethanol from Brazilian sugarcane.	Feedstock plantation and investing in production plant
February 2009	BP and Verenium	JV	Develop and commercialise cellulosic bioethanol from energy grasses, and further building production plant in Florida.	Energy grasses R&D and investing in production plants
August 2009	BP and Martek	SA	Conversion from sugar to biodiesel	Biofuels innovation

Source: Summarised by the researcher

5.3 Risk and Uncertainty Faced and Strategies Adopted by BP during the 1G Biofuels Deployment

Based on the literature (refer Table 2.4.2), according to Rosenbloom and Kantrow (1982), Pearson (1991), Rosenberg (1994) and the report from SpecialChem (2011), there are three types of R&U[136] arising from technology deployment, which would be faced by a private company. Table 5.2 summarises R&U faced by BP during the 1G biofuels deployment together with strategies adopted.

Table 5.2: Risk and Uncertainty from the 1G Biofuels Deployment and Strategies Applied to Counteract

R&U from the 1G biofuels deployment	Strategies applied
Business operations: Sustainability of biofuels deployment	-BP complies to the monthly biofuels reporting system and the Meta/Qualifying Standards-set by the RFA -BP communicates with the environmentalists at different levels -BP participates in four biofuels roundtables
Technology: Socio-Environmental implications (a) Land use (b) Food and Fuel Competitions (systemic risk) (c) Biodiversity threatened (systemic risk) (d) Ambiguity of the 1G biofuels carbon neutral cycle	(a) the NGB which can be grown from marginal land (b) Investment in Jatropha/energy grass as non-food biofuels feedstocks (c) Sustainability Standards Compliance to avoid the 1G biofuels threatening biodiversity (d) Validate high carbon saving and carbon neutrality Two examples: Sugarcane and Energy Grasses
Technology: Technical limitations of the 1G bioethanol	-Biobutanol introduction -Promoting biobutanol property and performance through BP's websites and corporate video -Vehicle and infrastructure testing on biobutanol
Social acceptance of biofuels	-Utilise the corporate media, in educating public about biofuels, promoting good criteria of biofuels and in answering biofuels controversy

Source: Summarised by the researcher.

5.3.1 Risk and Uncertainty of Business Operations

During the 1G biofuels deployment, BP faced a major challenge under the R&U of business operations, associated with the G&S criteria (refer appendix 5.3.1) of biofuels. This was further worsened by the emergence of two systemic risks (food-fuel competition and biodiversity threatened). Therefore, the G&S criteria have been enforced by the EU/UK Governments and pressured by the outspoken international/national environmentalists/social movements, as well as the international/national broadcasting/print media. These pressure groups/media were

136 business operations, technology and social acceptance.

pressing the regulators and the private companies like BP for the responsible of these two systemic risks. To counteract these R&U, BP responded through three strategies.

5.3.1.1 BP Complies with the Renewable Fuels Agency Requirements

To demonstrate its commitment in producing the G&S biofuels, BP as a company that imports biofuels into the UK does not use biofuels that come from unsustainable sources and violate the G&S criteria (guided by the Meta/Qualifying standards) required from the RFA. Furthermore, biofuels which do not have proper records and traceability are rejected from entering BP's supply chain (BP, 2009k). Supported by the interview: "The RTFO goes for a comprehensive strategy. Effective from 2008, companies are required to report their products (biofuels). So we have to be sure that for every month, how many gallons have been produced, where they come from and et cetera," commented the Sustainability Strategy Manager.

To maintain the sustainability of the biofuels supply chain, BP complies with the RFA Meta/Qualifying standards for two reasons. Firstly, the RFA standards are acting as guidance for the G&S biofuels supply. These two standards (refer appendix 4.1.3) specify clearly the biofuels criteria required to be supplied under the RTFO. Only biofuels which comply with these standards (at least the Qualifying Standard), will have the RTF certificate granted. Secondly, these two standards are the first attempt to create global reporting standards for biofuels. In the near future, BP will be required to report to the EU under the EU Renewable Energy Directive (EURED). Similar standards are gradually being developed in other parts of the world in order to ensure biofuels businesses are sustainable and be environmentally concerned.

Further explained by the Sustainability Strategy Manager from the interview: "We are currently developing ways to report on sustainability throughout our suppliers and supply chain, including the development of a management system for our biofuels operations. We have to include our joint venture partners. The management system will incorporate a number of parameters, including GHG emissions, biodiversity, water use, human rights etcetera." Therefore the G&S are not only emphasised on the product (biofuels), but also on the processes and resources utilised.

Further explained by the Sustainability Strategy Manager from the interview, apart from the compliance with the standards and rules set by the RFA, BP continuously exercises internal management for G&S biofuels product and production. For example, an Environmental Impact Assessment on feedstock plantations is conducted for biodiversity screening/assessment before plantation is located, while satellite imaging is used frequently to analyse topography/land activities[137].

5.3.1.2 BP Communicates with Environmentalists

BP's responsibility is to ensure that, its biofuels business can be greener and more sustainable. These messages have been delivered from its biofuels corporate policy (BP, 2009m) across the industry, to inform the related stakeholders, peers, JV-partners, regulators and also the general public.

Supported by two interviews: "We engage with other energy business partners, international bodies like the UN's Food and Agriculture Organisation, WWF, European Environmental Agency (EEA) many roundtables, governments, academic institutions and local NGOs where we operate. We explore many issues raised by biofuels feedstocks cultivation and production," commented the Executive of NWEEP. "We know the first generation biofuels have many pros and cons. We know that some of the activists will give opinions and this definitely will have some impact on us. We try to engage in as many kinds of work as possible, involve in a lot of development from local conservation to international preservation. So we do not work in isolation, instead we make sure we understand the bigger picture (for socioenvironmental conservation)," responded the Sustainability Strategy Manager.
Since 2005, BP has advocated for mandated international sustainability standards which include the consideration of the GHG impacts and reductions with other

137 to protect local biodiversity, to avoid high biodiversity areas/farms being converted as biofuels plantations.

socioenvironmental standards (BP, 2009l). This has been promoted through numerous roundtables participation and consistent communication with different levels of environmentalists. BP intends not only to gain the external supports for its biofuels business, but also to chart the path for a sustainable biofuels management system for global biofuels trading.

5.3.1.3 BP Participates in Various Roundtables

BP works with a range of stakeholders, including other organisations in the private sector[138], the international bodies[139] to the local public agencies or the NGOs[140] in countries where biofuels are produced, to understand many diverse issues that have been raised about biofuels production. BP understands that biofuels, if produced responsibly, can contribute to reductions in GHGs, improve energy security and create opportunities for rural development, particularly in developing economies. Supported by the interview: "BP is seeking to ensure that the crops used in biofuels production are produced in a sustainable manner. By encouraging standards for the production of feedstocks, BP is working carefully with the stakeholders (industry, regulator, roundtables and environmentalists) to prevent negative environmental and social impacts," said the Sustainability Strategy Manager.

In 2008, BP continues actively supporting and working in the Roundtable for Sustainable Biofuels (RSB), which then the RSB has produced "version zero"[141] of its sustainability standard for biofuels production. Subsequently, on 12 November 2009, the "Version One Principles and Criteria" was produced, which was a

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138 Private sectors: BP, Shell, Toyota Motor Europe, Petrobras and Bunge.
They are part of the Founding Steering Board members of Roundtable Sustainable Biofuels (RSB).

139 International bodies: WWF International, United Nations Conference on Trade and Development (UNCTAD), National Wildlife Federation, World Economic Forum, UN Foundation, Forest Stewardship Council, UN Environment Programme.
They are of the Founding Steering Board members of Roundtable Sustainable Biofuels (RSB).

140 Local GO/NGO: Swiss Energy Ministry, Fed of Swiss Oil Companies, Keio University, UNICA Sugarcane Industry Association Brazil, Energy Centre EPFL, TERI India, Brazilian Environmentalists, Mali Folkecentre, Dutch Ministry of Housing and the Environment.
They are of the Founding Steering Board members of Roundtable Sustainable Biofuels (RSB).

141 Version Zero is the first draft of the "Global principles and criteria for sustainable biofuels production" issued 13 August 2008 by the Roundtable on Sustainable Biofuels (RSB). This version drafted the principles for the release of the first official standards Version One in 2009.
Source: Roundtable on Sustainable Biofuels. 13 August 2008.

refinement/extension of the Version Zero, aiming towards a more comprehensive Sustainability Principles and Criteria for biofuels production. The RSB is a multi-stakeholder initiative aiming to drive the development of principles and criteria for sustainable biofuels production. Besides the RSB[142], BP is also member of the Roundtable on Sustainable Palm Oil (RSPO), the Roundtable for Responsible Soy (RTRS) and the Better Sugarcane Initiative (BSI) (BP, 2009l) (refer appendix 5.3.2).

In conclusion, through three strategies, BP (i) complies with the monthly biofuels "Carbon and Sustainability" reporting system based on the Meta/Qualifying Standards set by the RFA (ii) communicates with the environmental activists, and (iii) participates in four biofuels roundtables, these strategies show BP's commitment to the G&S biofuels requirement. These G&S criteria are not only going to determine the types of biofuels for current/future supply, but also are the key criteria for long-term biofuels business development.

Further explained by New: "For a biofuels industry to endure sustainability, it must avoid negative environmental and social impacts. In building the biofuels business, BP gives a high priority to sustainability and considers issues such as water resource availability, biodiversity, forest conservation, local labour and employment, communities and land rights, as well as environmental protection of water, soil and the atmosphere. We are committed to working with regulators and relevant stakeholders to develop market-based regulations that balance environmental, energy security and rural development goals that face communities around the world" (BP, 2007a).

5.3.2 Risk and Uncertainty of Technology: Social and Environmental Implications by the 1G Biofuels Deployment

From January 2008 to August 2008 (when the UK RTFO was launched on 15 April 2008), there was a widespread of debate within the British public questioning the sustainability of the 1G biofuels and its socioenvironmental implications. This was

142 BP as one of the Founding Steering Board members

driven by the occurrence of two systemic risks: food-fuel competition and diversity threatened; which were unexpected and carried great negative implications. Concerns were raised about whether using land to grow crops for biofuels may prevent growing enough food globally to feed a growing population. Other concerns raised were centered around biofuels leading to deforestation, contributing to soil erosion, farm land conversion into biofuels plantation, using excessive amounts of water and energy which lead to increasing CO_2 emissions-compared with conventional petrol/diesel production (BP, 2009l; BP, 2009m).

Supported by the interview, "The controversy is based on four misconceptions here. Firstly, biofuels necessarily mean all lands have to be sacrificed for their growing. Secondly, all food crops will turn into fuel. Thirdly, biofuels require the destruction of natural habitats such as the Amazon rain forest for growing; and fourthly, biofuels do not necessarily provide a significant reduction of full cycle CO_2 levels. Whether there is substance in these concerns depends very much on where the feedstock comes from, how it is farmed, how it is brought to market," explained the Executive of NWEEP.

As highlighted the interview, there are four main issues which concerned the 1G biofuels production: the land use, food-fuel competition, biodiversity threatened, and the carbon neutrality. These are four environmental implications of the 1G biofuels deployment, and BP has set the counteracting strategies to mitigate them.

5.3.2.1 Dealing with Land Use Issue

Through the undergoing R&D, the NGB not only will be expected to produce higher yields per acre, efficiently utilising limited marginal/idle land for their growth, but their production will also prosper the local agricultural sector. Therefore these feedstocks can be grown from lands which are not suitable for food, consequently their growing will not create land competition for food.

From the interview, "We carry out a biodiversity screening before we start every project. We have to avoid high-conservation areas to protect local biodiversity. Our biofuels projects in Brazil, India and the US (for biofuels plantations) incorporate areas that are not food cultivated, to protect water, flora and fauna. We are also making the development of standards for biofuels plantation require biodiversity assessments, through the Roundtable for Sustainable Biofuels, the Renewable Energy Directive, the RTFO and other initiatives. The satellite imaging has been used to help us to analyse these (land use, topography) and other impacts on the farms, make sure we manage the land well," explained the Executive of NWEEP.

"Around 1% of the world's arable land is used for biofuels production today, according to the UN's Food and Agriculture Organisation. This will increase towards 4% by 2030. Biofuels, although only expected to occupy a small fraction of arable land (by 2030), they have the potential to act as a catalyst, by bringing skills and techniques to improve agriculture more widely. This catalysing effect is likely to be most pronounced in poorer parts of the world, where growth in farming has usually provided higher employments and increase local productivity, a win-win situation I could say," commented the Sustainability Strategy Manager.

Even though the NGB would only be materialised five to ten years from 2008, the 1G has not be excluded from the G&S criteria. According to the Executive of NWEEP from the interview: "Look at the example of jatropha, they can be grown from marginal land and wasteland. Well, the energy grasses which also grew from set-aside land. Do not forget sugarcane which is grown away from the Amazon. These are fantastic examples as they are economically and environmentally sustainable."

The Brazilian sugarcane is one of the good examples which portrays its G&S criteria. This is one of the reasons which justifies BP have established a JV with Tropical Bioenergia since 2008. Brazil is producing around 22 billion litres of sugarcane ethanol per year, according to its industry organisation UNICA (refer appendix 5.2.6). With two harvests per year, sugarcane is plentiful in Brazil, studies show that there is enough arable land available to support the production of biofuels without having an impact on land for food crops, or on sensitive areas such as the Amazon rainforests. In fact the farming areas are distance 600 miles from the edge of the rainforest (Kolmar, 2009).

For other types of biofuels feedstocks, the land use rules for growing biofuels are part of the twelve principles in the Version One of Roundtable Sustainable Biofuels, then extended to respective RSPO, RTRS and BSI. Therefore, even before the arrival of the NGB, some precautionary actions have been taken to control the land use and to avoid further negative implications from biofuels plantation which could threaten the ecology.

5.3.2.2 Dealing with Food-Fuel Competition Issue

After the emergence of food-fuel competition debate, the UK Government has slowed down the expansion of biofuels. The RTFO targets have been altered to delay the 5% until 2013/14 instead of 2010 originally proposed. However, in reality, the 1G biofuels is still largely derived from grains. Apart from the continuous encouragement of using waste materials, and the enforcement of the G&S criteria for biofuels product and production, most of the political/corporate information is promoting the criteria of the NGB, which is switching away entirely from the food chain.

Through the NGB R&D, BP has concentrated on feedstocks that can make a big difference in reducing climate change without adversely affecting food security (BP, 2009m). From the interview: "We deliberately select feedstocks that have minimal impact on food production. Food issues are too sensitive nowadays. The dilemma of food-fuel in biofuels is one of the reason BP is investing into non-food crops like Jatropha (refer appendix 5.2.2) and biomass (refer appendix 5.3.3). Both represent the opportunity to meet the growth in demand for environmentally responsible and renewable transport fuels use," stated the Sustainability Strategy Manager.

“The ability to convert lignocellulose (biomass) could produce yield improvements of 25-100% in five to ten years from now,” observed Ian Dobson, Business Technology Manager. “But the process for converting lignocellulose to ethanol is more intensive, and it needs further technical development for this to become economically competitive. Lignocellulose conversion is a key area of work for the EBI which BP has invested in the research” (BP, 2007a). At the moment, Brazilian sugarcane is produced in a sustainable manner and which stands for more than 50% of the world bioethanol market share. The GM crops in the US (refer appendix 5.3.4), including the soy and corn also provide high yield which could fulfil the food, as well as the biofuels demand.

5.3.2.3 Dealing with Biodiversity Threatened Issue

BP has been investing in the NGB R&D since 2003. However, the NGB biofuels would not be commercially available for five to ten years from 2008/2009. As most of the R&D projects are still ongoing, the current 1G biofuels deployment is continuing to comply with the obligations of the EUBD (2003) and the RTFO (2008). Even though the G&S criteria have been emphasised in the NGB, the existing 1G is not being left leniently. The 1G which is largely derived from food crops, has to comply with various G&S criteria which have been drawn up by different stakeholders-the RFA, the environmentalists/social movements and every roundtables that have been established.

The fact is, every feedstock has different environmental performances (carbon savings) and implications: different degrees of fertilisation is required, different agrochemical are used and different impacts on water usage. Supported by the interview: “Some biofuels are good. They can improve energy security and reduce CO_2. Some have done less well, may have negative impacts on biodiversity or on the environment, and may not be able to reduce greenhouse gas as we might have expected. So we need to chose and develop the right one (through various R&D projects). Our strategy is to develop feedstocks that provide clean and reliable biofuels for transport. We are investing in feedstocks that minimise competition with food supplies and in technologies that are designed to create advanced fuels with higher energy content for environmental benefits," explained the Executive of NWEEP.

Further explained by the Sustainability Strategy Manager from the interview: "A certain sustainability standard that I am currently working on implies, for example, if biofuels comes from land that has been deforested, the product is technically illegal in Europe. When I buy ethanol from Brazil, the supplier needs to guarantee that, since November 2005 that land has solely been producing sugarcane. Let's say that if sugarcane is grown from a reconverted forest, I can't buy that product. It is a consequence of deforestation! So these are some kinds of thing that we will look at, in order to prevent people just chopping down the Amazon." The Manager's view is also backed by the Forbes news which published "BP's strategy is to focus on better, more sustainable biofuels only," said Susan Ellerbusch, President of BP Biofuels North America. "Good biofuels can make significant contributions to reducing GHG emissions and can be produced in an environmentally and economically sustainable manner" (Thurmond, 2008).

Reflected from the interview and published information, BP is seeking to ensure that the current 1G biofuels used is produced in a sustainable manner. By applying internal control [143] and by comply with the standards drawn at roundtables collectively; BP demonstrates its efforts to ensure that only G&S biofuels are permitted to be deployed within its supply chain.

5.3.2.4 Dealing with Ambiguity of the 1G Biofuels Carbon Neutral Cycle

In theory, the CO_2 emissions of biofuels should be far less than the emissions arising

143 Internal control includes:
-only purchase G&S biofuels,
-transparency in biofuels data reporting system to comply the RFA "Carbon and Sustainability" reporting system, as well as the Meta/Qualifying standards.
-rejecting biofuels which are illegal, unethical (deforestation/farm conversion) and improbable (lack of appropriate data),
-biodiversity assessment/screening before every project started, and satellite monitoring.

from crude oil production. This is particularly important for the UK, since the main objective of using biofuels in the UK is to reduce the GHG/CO_2 emissions. The mechanisms of biofuels carbon savings are working in two ways: saving from tailpipe and carbon neutrality (refer appendix 5.3.5).

Supported by the interview: “The concern over the environment continues to rise. On one hand we need to keep economies and societies developing while at the same time, we have to limit our carbon footprint. Biofuels covers all liquid fuels made from biomass, which is an organic plant material containing energy obtained from sunlight that the plant stored when it grew. This stored energy can then be converted into liquid fuels, provided this conversion process is efficient, and depending on the type of feedstock used. Biofuels can help reduce greenhouse gas. Biofuels crops can absorb CO_2 that helps to offset the CO_2 produced when burnt in vehicles,” said the Sustainability Strategy Manager. Therefore, the actual CO_2 reduction achieved by biofuels is determined by two factors: the types of feedstock used and the activities conducted along the value chain.

(a) Types of Feedstock

There are good and bad biofuels. Good biofuels are non-food, and those which can be grown under low-quality conditions (wasteland), require no agrochemical/fertiliser and have a low water footprint; yet naturally produce a high yield. The example of good biofuels are energy grasses, sugarcane and jatropha, all of which have a low impact on natural habits, require low energy input and do not compete with food yet capable of a high yield to provide high energy content.

(b) Activities along the Value Chain

Energy is needed to grow and harvest raw materials, to convert them into biofuels and then to distribute them. Each biofuels can take a different path which then determines the amount of energy needed from growing, fertilising, harvesting, processing through to distribution. Explain during the interview, “In reality, biofuels must be compared with fossil fuels on a “crop-to-car” basis. This will take into account, all the inputs required: their manufacture, their use of farm equipment and fertilisers, their energy use for transporting the crop, the plant and the conversion process, almost every stage of the process" said the Fuel Engineer.

According to Koonin: firstly, to cultivate the crops, we use energy in farming and CO_2 is produced from farm vehicles or fertiliser manufacture. Then, the process of converting the starches in the crop to biofuels also requires external energy to be used in the conversion process. Next, transporting and distributing the fuel to the market soaks up even more energy before the fuel actually gets into the automobile. The net effect is that to make one energy unit of corn based bioethanol in the US requires around 0.9 energy units of external energy (Knott, 2007).

Secondly, on a crop-to-car basis, the full bioethanol life cycle takes account of the CO_2 taken in by the plant as it is growing. However, as bioethanol is mainly used as a blend with gasoline, presumably at 10% maximum by volume for the current requirement, a tank of blended bioethanol would therefore deliver less than 2% overall reduction in emissions compared with a tank of gasoline. Given the fact that the world's transportation fuels account overall for 21% of total global emissions, the potential reduction in global emissions from bioethanol blended fuels is indeed limited. "It is an improvement in emission, no doubt, but not sensational," observed Koonin (Knott, 2007).

Dobson explained: "There is no one magic number which describes emissions reduction for all biofuels. These vary enormously depending on the feedstocks and processing involved. By way of illustration, the crop to car numbers, say, bioethanol made from US corn in a well-operated business, could show a 30%-40% reduction in CO_2 emissions compared with gasoline on an energy equivalent basis. However, the Brazilian sugar cane bioethanol, which uses more of the original crop in the overall process for energy generation, could show a 85%-90% CO_2 reduction" (BP, 2007a).

Supporting by this research, BP has made careful choices about the feedstocks use, such as jatropha, energy grasses (refer appendix 5.3.6) and sugarcane, because they can deliver significant life cycle GHG reductions of up to 90% (sugarcane) compared to fossil fuels. These feedstocks are also perennial crops that contribute to the carbon neutrality (BP, 2009o). "In summary, it would be fair to say that if biofuels manufacture is done well, then biofuels can make a contribution to emissions reductions," said Dobson (BP, 2007a). A well done biofuels manufacture can help to reduce GHG emissions, improve energy efficiency and stimulate agricultural progress. If they are done less well, they can have potentially more negative impacts on natural habits and make little or no tangible difference to climate change (BP, 2009n). The identification of Brazilian sugarcane which could have 85%-90% of CO_2 reduction encouraged BP to have a JV with Tropical BioEnergia for the first sugarcane bioethanol production plant establishment in 2008 (refer appendix 5.3.7).

5.3.3 Risk and Uncertainty of the Technology: Technical Limitations of the 1G bioethanol

Bioethanol has a lower energy content than the fossil fuel counterpart. Bioethanol provides around 2/3 energy compare with conventional gasoline (BP, 2007a; Knott, 2007). Low energy performance of bioethanol would reduce energy efficiency and obstruct higher bioethanol adoption. Explained by the Fuel Engineer from the interview: "As such, greater bioethanol volumes are required to match with the conventional gasoline. When greater volumes are required, it will result in using biofuels more, which will not help at energy efficiency, but will put more pressure on the feedstocks growing." The Fuel Engineer from the interview continued: "Giving the limitations of current biofuels, biofuels are not capable enough to be adopted for neat use (100%). They are used commercially by blending with gasoline at levels which are dictated by chemical properties or handling considerations for the car warranty."

Apart from lower energy content, bioethanol is also carrying other limitations. Further explained by the Fuel Engineer from the interview, the volume of biofuels mixed with conventional fuels is limited by chemical properties or perhaps the implementation issues connected with their handling. For use which is more than a 10% blend requires engine modifications to be made.

“Bioethanol could be corrosive to engine components such as seals and gaskets as well as certain alloys, if used at higher concentrations than 10%. In addition, it easily absorbs water, allowing it to separate out from the gasoline blend in storage tanks, fuel tanks or in the distribution pipelines. It also has a higher vapour pressure than gasoline. Hence, it can evaporate from vehicle fuel tanks. These are properties which are unwelcome in transportation pipelines, distribution depots and at retail sites,” said Dobson (BP, 2007a). “To counter bioethanol's undesirable properties, some automobile manufacturers make new vehicles with flexible fuel engines that can either run on blends containing up to 85% bioethanol (E85) or can be switched to 100% gasoline. However there are relatively few of these vechicles in use on the UK roads as they are still expensive,” said the Fuel Engineer from the interview.

5.3.3.1 Strategies to Solve Bioethanol's Limitations: Biobutanol Introduction

According to Dobson, “There is a need to find a better performing bio-alcohol, one which can be blended at a greater percentage into conventional fuels, above the current 10% threshold. The alternative to this is to change the design and manufacture of all the world's automobile engines, which would be not only a massive undertaking but also a very slow process,” (BP, 2007a).

Thus, BP has developed a better solution-to introduce biobutanol. BP has been working with DuPont since 2003 in developing biobutanol. BP and DuPont recognise that, while the existing bioethanol has proven to be a starting point for biofuels introduction, there are limitations of bioethanol that need to be resolved in order to increase market penetration (BP, 20 June 2006). “Our collaboration with BP, not only improve the bioprocess to produce commercial volumes of biobutanol, but also to pursue an integrated commercialisation strategy that incorporates building pilot and commercial scale facilities,” said David Anton, DuPont Biofuels Venture Manager (BP, 14 February 2008).

"The feedstocks[144] for making biobutanol are the same as those used for bioethanol manufacture, and the front end of the process is also similar," explained Dobson. "For the fermentation stage for converting sugars and starches to alcohol, DuPont's bioscientists have identified a different microorganism that produces biobutanol" (BP, 2007a).

To date, biobutanol has been successfully developed in a laboratory. BP and DuPont are building a demonstration plant for biobutanol situated at Saltend, Hull (BP, 2009h; 2009q). The biobutanol plant will be able to produce around 20,000 litres/a year from a wide variety of feedstocks. Another advantage of the biobutanol process is that, it can be adapted to existing bioethanol plants with only minor changes to the fermentation and distillation stages, therefore opening up the possibility for a full scale biobutanol production in the near future (BP, 2007a).

5.3.3.2 Promoting Chemical Property and Performance of Biobutanol through BP's Websites and Corporate Video

From 2006 to 2009, BP used its corporate websites[145] and a corporate video[146] not only to promote the good properties and performance of biobutanol, but also to educate the public about this new product. The websites and corporate video allows a 24/7 accessibility which attract those who are interested in knowing the latest information about BP's biofuels business. It is forecasted that biobutanol will be available in the UK from 2013/2014.

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144 Biobutanol could be produced from variety of conventional feedstocks such as sugarcane, corn, sugar beet, wheat, cassava and sorghum, as well as future biofuels feedstocks such as lignocellulosic from energy grasses or agricultural by-products (BP, 2008e).

145 These four BP websites are:
(a) BP. 20 June 2006. BP and DuPont Announce Partnership to Develop Advanced Biofuels. [Online]. Available at: http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7018942
(b) BP. 2007a. Bringing on Biofuels. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9021004&contentId=7038907
(c) BP.14 February 2008. DuPont and BP Disclose Advanced Biofuels Partnership Targeting Multiple Butanol Molecules. [Online]. Available at: http://www.bp.com/genericarticle.do?categoryId=4705&contentId=7041073
(d) BP. 2009h. Biobutanol: An Advanced Biofuels. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9027831&contentId=7050737

146 BP. 2008. Biobutanol. [Online]. Corporate Video. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9030051&contentId=7055185

In general, biobutanol[147] is an organic alcohol having four carbon atoms in its structure with twice as many as in ethanol. It has been used in the chemicals industry, for example as a solvent for many years, but has not been considered for large scale use due to its high production costs. The development work undertaken by BP and DuPont looks set to lower the production costs by employing new biotechnology processes to produce biobutanol at maximum output and to achieve high production efficiency (BP, 2007a).

BP considers biobutanol as an “advantaged molecule” when it comes to acting as a fuel. Biobutanol's energy content is nearer to petrol-86%, compared with bioethanol at 67%. This means in practical terms for the customer, a fuel tank of biobutanol blended gasoline will go further than a bioethanol blend, and offers better fuel economy by improving a car's fuel efficiency and mileage. Biobutanol can be used in conventional ICEs at higher concentrations, up to at least 16%. It has low water affinity, thereby removing the risk of phase separation in storage tanks and vehicle fuel tanks, and can also be transported in pipelines. Besides, it has a lower vapour pressure compare to bioethanol, which reduces evaporation losses and makes it easier to blend (BP, 20 June 2006; BP, 2007a).

The successful R&D of biobutanol shows that the chemical property can be blended at 16% of biobutanol with 84% of petrol, which is a good start for a higher percentage of biodiesel use in the ICEs. The allowance of 16% biobutanol thereby displacing more gasoline per gallon of fuel consumer than the standard 5-10% by volume of a bioethanol blend (BP, 2009h). Hence, the 16% biobutanol blend has a greater potential to reduce more GHG emissions than the 5-10% bioethanol blend.

5.3.3.3 Vehicle and Infrastructure Testing on Biobutanol

Further explained by Jean-Charles Dumenil, Programme Manager for BP Biofuels: “For more than a year, BP Biofuels in conjunction with the company's fuels technology teams in the UK, USA and Germany; have been putting biobutanol

147 butyl alcohol or C_4H_9OH

through a number of screening tests. Investigations have included health and safety aspects, blending attributes focusing on chemical and physical properties, compatibility with existing supply networks and the suitability of biobutanol to be used in the existing automobiles" (BP, 2007a).

For in-situ automobile tests, a large fleet of new and used vehicles, having different engine sizes and from different technology generations are being tested-both in controlled test chambers and on public roads. By using different biobutanol concentrations, parameters are being checked include material compatibility, engine cleanliness, power and acceleration, fuel economy, emissions, and drivability in hot and cold weather. "All tests carried out to date have shown encouraging results, with no significant negative impact compared with conventional fuels, and key advantages compared to ethanol," added Dumenil (BP, 2007a).

According to Frank Gerry, BP Biofuels Program Manager: "Biobutanol formulation that meets key characteristics of good quality fuel includes high energy density, controlled volatility, sufficient octane and low levels of impurities". He described testing data, indicates that biobutanol fuel blends at a nominal 10% level perform similarly to unleaded gasoline fuel[148].

According to the latest BP's corporate report, the fleet testing conducted by BP-DuPont of biobutanol (in actual vehicles on roads), covering a distance of more than 1.3 million miles, has confirmed the performance of biobutanol. Biobutanol blended at 16% into fuels demonstrated an excellent vehicle performance, affirmed the compatibility of biobutanol with the existing fuel infrastructure and pilot testing on consumer satisfaction with the product (BP, 2009h). Further commented by Dobson: "On the basis of the vehicle test results, we are now announcing that high octane biobutanol offers a way to break through the 10% limit with bioethanol in the current vehicle fleet" (BP, 14 February 2008).

148 Bioethanol is ranged 21.1-21.7 mega joules per litre (MJ/L), Biobutanol is ranged 26.9-27.0 MJ/L which is closer to the gasoline 32.2-32.9 MJ/L (BP, 19 April 2007).

BP is also working with Ford Motor Company, to substantiate the performance and environmental benefits of biobutanol as a gasoline blending component. Since 2007, BP and DuPont have been conducting vehicle and infrastructure product testing of biobutanol. 3 million litres of corn-based biobutanol has been used. The fuels are then blended into gasoline at a UK terminal.

The testing has been built upon initial laboratory engine tests using biobutanol, which indicated that biobutanol has similar fuel performance properties to unleaded petrol. Richard Parry Jones, Chief Technical Officer, Ford Motor Company responded: "Ford welcomes this initiative and is optimistic that biobutanol will add significantly to the range of biofuels technologies available. BP and DuPont's actions are entirely consistent with our own aspiration to develop sustainable mobility solutions (BP, 2009h).

5.3.4 Dealing with Biofuels Social Acceptance: Corporate Media Utilisation

Apart from the UK/Scottish Government efforts in seeding public acceptance of biofuels, BP also, through its corporate website, set up a flash animation interactive "Watch and Learn"[149] and "Biofuels Feedstocks"[150] aimed to educate the general public about the general knowledge and the development of biofuels in order to create public acceptance of biofuels.

The "Watch and Learn" website is an animated page, well-set up containts concise information on ten pages for the readers to browse through. It explains the biofuels supply chain, introduces the conventional biofuels feedstocks: beginning at the farms, processing factory, finally reaching the BP kiosk. There are several issues being addressed, such as: BP research work in the NGB development by using non-edible crops and fast growing grasses with environmental sensitivity concerns; the

149 BP. 2007c. Watch and Learn. [Online]. Available at: http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/complex_flash/bp_complex/bp_biofuels_animation_v7.swf

150 BP. 2008f. Biofuels Feedstocks. [Online]. Available at: http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/complex_flash/bp_complex/MainMovie6.swf.

good criteria of sugarcane; and BP working with DuPont and Verenium in producing biobutanol. The advantages of biobutanol have been highlighted as a product which has higher energy content, compatibility with petrol and better carbon neutrality. The "Biofuels Feedstocks" is another animated website, which explains seven different feedstocks[151] that are used in producing biofuels. Sugarcane has been promoted by this website with a brief description about its good criteria which enable a 90% GHG reduction compare with petrol. Besides, wheat has also been explained; and details the work carried out by BP, DuPont and British Sugar have formed a JV, to construct a plant to produce bioethanol from wheat in the UK.

These two animated websites are designed to provide short and brief information about BP's biofuels. The information is rather general and straight forward for readers without profound scientific knowledge of biofuels to understand the messages given. Apart from information/knowledge sharing, these two animated websites are promoting BP's environmental concerns regarding G&S biofuels' feedstocks cultivation, which demonstrates BP's commitments as one of the leading green biofuels suppliers/producers. BP is also sharing its continuing R&D in biobutanol-a new product from BP and giving readers more information about developing biofuels to gain public support. Interested reader who visit these two websites will not only gain a general knowledge about biofuels, but also will learn some basic information of BP's biofuels businesses, particularly will encounter the biobutanol as a new product after years of knowing bioethanol. The websites do not provide a section for readers/consumers' feedback. However, visitors to the website can write to BP using the "contact us" section on the website.

5.3.4.1 Utilising Websites and Corporate Videos in Responding Biofuels Controversy

In the UK, the strong debates on food-fuel competition, food price increased and biodiversity damaged (resulted from the systemic risks) have contributed to firing up

151 The seven different types of feedstocks in the BP's Biofuels Feedstocks website are: sugarcane, corn, wheat, energy grasses, soya, rapeseed and jatropha.

the controversy and create further public anxiety on the biofuels issues. For the period January 2008 to September 2008[152], the British public was subjected to a nearly daily update and continuing debate on these issues from all media sources: television, radio, newspapers and the internet. This period marked two stages-before and during the effectuation of the RTFO since 15 April 2008. Various media fuelled the debate and decreased the public confident on biofuels, which nearly ruined the RTFO effectuation and threatened the oil companies' biofuels businesses.

Supported by two interviewees: "What we can see from here is, how the mismanagement of biofuels has caused the trouble. There are so many speculations. Today biofuels is using up 1% of the world arable land but look how much noise the media made in the speculation," said the Sustainability Strategy Manager. "What we can do is to explain and to educate, through our corporate media (homepage, publications, magazines, newsletters); and support this with scientific evidence to back it up. We do not have a broadcasting media which can keep on telling the facts, we use our homepage the most," explained the Executive of NWEEP.

5.3.4.2 Balancing the Business, Environment and Sustainability Commitment

After the emergence of systemic risks, the UK Government amended the RTFO targets, but did not abandon biofuels deployment totally. This decision has reinstalled confidence within the oil companies to continue their biofuels business in both biofuels supply and the NGB R&D. From the interview, the Sustainable Strategy Manager explained: "Right now, we are in the process of dealing with the (RTFO) targets and the RFA's Indicative Targets. So everybody is kind of aligning towards these targets. If the UK Government terminates it (biofuels deployment), then it will send the wrong message to the public about biofuels, and it will discourage the industry. I think the current legislation has a very weak criterion concerning the definitions of sustainability, but I hope it will grow stronger in the future."

152 In September 2008, the British public is alarmed by the news of Lehman Brothers filing for bankruptcy, which marked the beginning of world financial crisis. This date could be traced through BBC (16 September 2008). The biofuels debates were cooled down, and the public attention switched towards this financial crisis.

“You have to realise one thing, that for some reason, biofuels are the scapegoat for environmental and social power. You might get cut out if you project the idea in conversation, that in reality this is going to correspond to biofuels. So, we need to tackle (these debates), let’s say how much land is available, how much we can use without touching any high value area and show how we do not take food to produce biofuels. Biofuels is taking the blame for it, but in reality is all about the agriculture and land management,” the Sustainability Strategy Manager from the interview added.

The manager's view is supported by Hayward's corporate speech. In balancing BP’s business performance, environment and sustainability commitment, Hayward replied: “I don’t see a distinction between sustainability and performance. My aim for BP is that its performance should be sustainable; in other words everything we do each day should contribute in some way to the long-term economic health of BP and that of the environment and society. We measure performance accordingly, not only with financial metrics but also with the data on safety and the environment. We are looking to the future as well as the present and I believe that is the foundation for responsible and best-in-class performance” (BP, 1 April 2009).

“If biofuels are introduced in a responsible and sustainable way, their growth could be phenomenal. For this to occur, biofuels must retain government support, public awareness and goodwill must be secured and maintained, and technology must play an effective and timely role. By accessing biofuels feedstocks that do not compete with food stocks, that do not encroach on the rainforest or other sensitive areas, and that take account of the biosphere and biodiversity, we believe biofuels can make a valuable contribution to the world's energy supplies, and do so in a manner that is sustainable and profitable,” New (BP, 2007a).

5.4 Risk and Uncertainty Faced and Strategies Adopted by BP during the Next Generation Biofuels Development

According to Hayward: “BP’s projections suggest we need around 45% more energy in 2030 than we consume today, and double what we consume today by 2050. Currently, the 1G biofuels manufactured primarily from agricultural crops, account for only 2-3% of global transportation fuels. However BP estimates the demand for biofuels could grow up to a 30% share of the market by 2030" (BP, 2007a, BP, 4 February 2010). Thus the future biofuels must comply with socially and environmentally acceptable ways. With several first mover actions already set in place by BP in the NGB development, BP has established itself at the forefront of this anticipated demand growth.

Extending the three driving forces which led to the commencement of the 1G biofuels (discussed at 5.1.1), BP recognises that today's biofuels deployment are just a start, which has provided an open door for a long-term business prospect. Supported by the interview: "One of the purposes for the next generation biofuels research, we believe that the new generation biofuels are the better solution. We are using the first generation as a stepping stone to create the necessary capacity and market alignment before we go into the second generation," said the Sustainability Strategy Manager. Therefore, the potential of biofuels would only be unlocked through R&D, which aimed at expanding the potential of biofuels: solving the limitations of the 1G biofuels; complying with the G&S criteria and producing biofuels in the most efficient way (high volume at lowest production costs). By applying bioscience and biotechnology into the industry, various R&D projects will build BP's competitive advantage by creating a new generation of G&S biofuels.

Based on the literature (refer Table 2.4.1), there are three R&U[153] arising during the technology development. Using the theories advocated by Rosenbloom and Kantrow (1982), Pearson (1991), Rosenberg (1994), the researcher has identified various strategies which BP has adopted to deal with them. As shown in Table 5.3, these are the R&U of the NGB deployment together with the strategies implemented.

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153 innovation process, technology, and social acceptance.

Table 5.3: Risk and Uncertainty from the NGB Development and Strategies Adopted to Counteract

The NGB development	Strategies applied
Innovation process -Beyond BP's institutional knowledge and capability at the NGB development and production	-BP established various partnership with (commercial and academic) biotechnology institutions and agricultural industry
Technology -Limitations of the NGB to meet increasing demand	-BP diversify the NGB innovations on feedstocks and process development
Social acceptance of the NGB	-Utilise corporate media, in educating public about the NGB biofuels, promoting good criteria of biofuels.

Source: Summarised by the researcher.

5.4.1 Dealing with Risk and Uncertainty of Innovation Process

There are two R&U faced by BP. Firstly, the profound biofuels technology has challenged BP's existing institutional knowledge. Even centuries of fossil fuels business expertises could not answer the technical ambiguity of the NGB on both product and production innovation. Secondly, the incapability of BP in producing the NGB at commercial scale. This is because BP's existing infrastructure is at fossil fuels extraction and refinery. Hence, to go from an oil mining operation to biofuels farming, this has created a knowledge gap for BP. Supported by Koonin: “Changing from BP's core oil and gas exploration business is a slow process. We are trying (but) it is not easy to change things. You can't cut off the present. Deployment of energy innovations (from oil and gas to biofuels) is very hard because of entrenched interests” (LaMonica, 22 September 2008).

As such, BP is collaborating with various cross nations biotechnology institutions (commercial and academic), and agricultural industry in order to achieve two objectives as below:

(a) To access biofuels R&D and production facilities

For the NGB development, some advanced research and production facilities are required. Since biofuels is a new business for BP, to build these new infrastructures alone would involve high costs and high risks. Though partnerships, BP could have the direct and immediate access to its partners' existing R&D[154] and production facilities[155], or at least to share the building/operation costs together to have these facilities established. These partnerships could reduce BP to the risk exposure of high investments, and will help BP to move into the NGB development and production at a speedy manner.

(b) Access and secure biofuels feedstocks

The nature of the feedstocks growing is determined by the geographical factor. Due to the geographical advantage of some nations, like jatropha in India (BP funds TERI), jatropha (BP JV with D1 Oil) in Southern Africa and South East Asia; and sugarcane in Brazil (BP JV with Tropical Bioenergia), all of these countries have the absolute advantage in executing large scale feedstocks growing. These three cross-border JVs reflect BP's objectives in securing these feedstocks, which allow BP to have a higher control in biofuels value chain (from source to production), and could build up its capacity for future supply.

Two of the objectives mentioned above could be summarised as BP’s intention to access its partners' institutional knowledge and capability. Although BP has established[156] different types of collaboration, all of them are concentrated on BP's main principle: the need for external expertises to complement the inadequacy of internal institutional knowledge at the NGB development and production within BP. Supported by New: “To understand the impact of technology on biofuels development, BP is learning the dynamics of the new biofuels value chain, enabling the company to inform its technology development programmes, to build key competencies and secure asset positions” (BP, 2007a).

Looking at a bigger picture, the collaborations not only are benefiting BP, but also its partner under a symbiotic relationship. The implications of these collaborations will

154 BP sets up EBI, BP-Mendel, BP-Arizona University, BP-Martek (refer appendix 5.2).
155 This is evidenced by BP three JV projects: BP-Tropical BioEnergia; BP-DuPont-British Sugar, and BP-Verenium (refer appendix 5.2).
156 direct funding, joint venture (JV) and strategic alliance (SA)

contribute to the social and economic gains for both companies, as well as for the location where the investments are made. BP could access its partners' expertises and capabilities at the NGB development/production, tap into its partners' resources (land, skilled workers, infrastructures), as well as strengthening the local market accession (to deal with the issues of different culture, regulations, economic and business system). Meanwhile, its partners could also access BP's knowledge and capabilities at fuel supplying, the brand of BP, obtaining investments from BP (for wealth creation and employments) as well as global fuel market accession which could assure profitable opportunities.

5.4.2 Dealing with the Limitations of the Next Generation Biofuels to Meet Increasing Demand

BP estimates that around 7-10% of current global transportation fuel demand can be met by the 1G biofuels feedstocks presently in use, along with the cultivation of additional land, without affecting food supplies. However, this is only valid for a short-term biofuels implementation within five-to-ten years (BP, 2007a). As such the NGB has to be developed further to increase the capacity for future supply to satisfy the future demand.

Yet, there is one issue questioning the capacity of the NGB: How far can the NGB meet the world's biofuels increasing demands? If the EURED (2009) has specified 10% of renewables should form the transport fuel, how much could biofuels contribute to achieve this target? Recall the ten NGB projects (refer appendix 5.2), they range from biofuels research (on product and process technology), feedstocks plantation, and also investments in production plant; all signify the strong start in charting BP's biofuels business for many years to come. The diversification of the NGB is important, to ensure each of the project from different generations, different types of feedstocks, as well as different production approaches could contribute significantly to strengthen the capacity of the NGB production.

5.4.2.1 Intensify the Next Generation Biofuels Research on Feedstocks Development

According to Knott (2007), the pathway to increase biofuels lies in being able to access other substances in plants which are present in greater proportions than sugars and starches, called as biomass/lignocellulosic categorised under the 2G biofuels. Scientifically, under photosynthesis, most of the sun energy is converted not only into sugars and starches, but also into cellulose, hemicellulose and lignin[157]. These substances, collectively referred as lignocellulosic biomass, essentially form the cell walls, the structure and protective armour of the plant. In some agricultural crops such as corn and wheat, this type of biomass is contained in the agriculture residues, like corn stove and wheat straw (Knott, 2007).

Energy grasses[158] are one of the potential the 2G biofuels feedstocks. Such plant species produce biomass rapidly with the potential to more litres of biofuels per acre than other feedstocks. For example, 420 litres of bioethanol could be obtained per tonne of biomass. Some experts believe the dry biomass yields could be pushed up by perhaps another 40% on top of these volumes. Furthermore, these perennial grass species can grow well without the need for intensive inputs such as agrochemicals/fertiliser, and have the ability to thrive on marginal land where more conventional crops would not survive. In this regard, their mass cultivation would not pose a threat to the prime agricultural land and food production (Knott, 2007). Through a technology partnership with Verenium, BP-Verenium is developing the cellulosic biofuels made from energy grasses such as miscanthus, switchgrass and sorghum. Besides, the EBI is also developing the 2G biofuels from biomass (BP, 2009q).

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157 Cellulose is a polymer of glucose, a sugar containing six carbon atoms. Hemicellulose is other sugar polymers with five carbon atoms. Lignin is a refractory substance of aromatic carbon compounds.

158 Miscanthus, a species of tall grass, can quickly grow to over 3m in height in densely packed fields. Switchgrass, another tall, woody-stemmed grass, exhibits similar growth. Both of these can yield over 10 tonnes of dry biomass per acre in a year (BP, 2009k).

5.4.2.2 Intensify the Next Generation Biofuels Research on Process Technology

To achieve higher efficiency on production, the NGB R&D is also focusing on the process technology. To date, there are three projects which BP has established with its partners. Firstly, BP-Arizona State University and Science Foundation Arizona. This partnership is aimed to produce biodiesel using photosynthetic bacterium. The advanced process eliminates the need for costly and complex processing infrastructure, allows a direct conversion from bacterium into biodiesel without going through the process of transesterification which could lower down the production cost. Furthermore, the direct conversion by using solar power could eliminate the energy inputs, which resulting in lower CO_2 emission.

Secondly, BP-Verenium and EBI. According to Koonin, genetic engineering has to be applied to the plants, to unlock their potential as biofuels feedstocks (Knott, 2007). Since Mendel's core expertise is about plant gene, its institutional knowledge of gene function enables the identification of natural/synthetic chemicals that can improve plant productivity resulting in higher yields with minimal resources needed for growing.

Koonin further commented: “We have to acknowledge that lignocellulose is tough for enzymes to break down into starch and sugar molecules for fermentation. To make this feasible, chemical and physical treatments of the biomass are currently required to break down the cellulose into fibres, which enzymes can decompose these fibres into component sugars, before the fermentation microbes can get to work in producing ethanol” (Knott, 2007). To enhance production efficiency, BP scientists/researchers are finding ways to make these enzymes more cheaply than is possible at present, and also to seek microorganisms that are capable of fermenting the five-carbon atom sugar molecules found in hemicellulose. At the moment, BP-Verenium and EBI are actively engaged in enzyme development to materialise the production of cellulosic bioethanol.

Thirdly, apart from BP's current investments in Jatropha-which will provide a massive amount of biodiesel feedstocks for the near term, another division of biodiesel development is carried out through the Joint Development between BP and Martek. This collaboration is working on the process technology, by converting sugars into biodiesel. According to BP's corporate report (2009r), the technology uses microorganisms that convert sugars into lipids through fermentation. The oil that is produced can then be extracted and processed into biodiesel. There are a few advantages of the sugar-to-diesel pathway over conventional biodiesel made from food crop-feedstocks diversification, price stabilisation and high GHG/CO_2 reductions (refer appendix 5.4.1).

Furthermore, BP justified the sugar-to-diesel technology by admitting it is reliant on technologies that are already proven at scale for its applicability, rather than technologies that are still in the lab-stage of development. Currently, a number of organisms for the conversion process have been identified. However, the challenge is to identify the most suitable one with high efficient manufacturing methods, to enable a cost effective production at a commercial scale. BP expected this technology will be viable in the market within five years (BP, 2009r).

5.4.3 Dealing with Risk and Uncertainty of Social Acceptance

After the emergence of the systemic risks, the 1G is under controlled by the RFA- which set mandatory requirements on G&S biofuels supply and indicative targets for the oil companies/biofuels suppliers. While the NGB R&D is still ongoing, the ripple effects of the systemic risks that arose are eroding the social acceptance about its reliability on G&S criteria. BP through its corporate website and videos is promoting both the benefits provided by the NGB, as well as its latest the NGB development news. BP’s goald is to build a sustainable biofuels business which is based on proprietary technology, ownership of advantaged assets, logistics and feedstocks. With its current portfolio of activities in developing the G&S NGB feedstocks, and its active involvement in the current biofuels supply market and development of efficient the NGB process technology, BP has established a leading position within the industry (BP, 2007a).

“Today, we invest a significant amount in alternative energy technology compared with our peers. We are prioritising areas with significant long-term growth potential: biofuels (also wind, solar) and we directed the majority of our $1.4 billion investment in low-carbon energy in 2008 to these areas,” said Hayward (BP, 1 April 2009). Supported by the interview: “We have engaged on all these (R&D and investments), and obviously we agreed that second generation is the way to go. The last thing that we do not want to do is to allow biofuels to destroy biodiversity and to compete with food directly,” commented the Sustainability Strategy Manager.

On 30 October 2009, BP’s biofuels business was voted as “Biofuels Corporation of the Year 2009” by the World Refining Association (WRA)[159] at its 4th annual Biofuels Conference dated on 27-29 October 2009 in Budapest, Hungary. The award acknowledged BP's efforts in biofuels deployment and development. BP Biofuels was elected as the first recipient of the award by more than 350 biofuels industry players, policy makers, related associations; and was endorsed by the Advisory Board of the WRA (BP, 30 October 2009). This award is important for BP, because as it acknowledges BP's contribution in G&S biofuels.

5.5 Conclusion

The mechanisms that the regulators devised to deliver biofuels deployment and development, have built up a strong confidence for BP in executing biofuels supply and pursuing the NGB development, despite the high risks/investments involved. Backed by the three political driving forces[160] from the regulators (of different levels) for biofuels adoption, BP's rationales to engage in biofuels business are seamlessly matched with these driving forces, and which were also strengthen by its economic motivations. Biofuels are one of the RE profiles that could sustain BP’s energy business for many years to come.

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159 The World Refining Association (WRA) is an independent, information provider to the global oil and gas and energy sectors. Formed in 1997, has offices in Central London and Cheltenham in the UK, and operates a team of independent senior consultants based across Europe, Russia and the Middle East (WRA, 2009).
160 energy security, GHGs reduction, and prospering agriculture industry

Operating within a regulated market, the biofuels market has continuous intervention from the regulators. BP as one of the biofuels suppliers has to comply with the rules, regulations and requirements laid down by the regulators, in order to perform its function and to sustain its biofuels business. When technological change incurred R&U (some of which are expected), these were resolved by BP efficiently/effectively with the combined strengths, knowledge and resources which it had established with its business partners, as well as collaborations with the regulators at various level.

The systemic risks occurred were unanticipated. Most of the solutions were provided by the regulators due to their political authority/position and roles they played. Consequently, biofuels targets of the RTFO were altered, in order to slow down biofuels expansion. Inevitably, biofuels deployment continues, and facilitated with stringent G&S criteria enforcement. This research highlights that, BP took these systemic risks as one of the events on its learning curve, to control/manage its internal biofuels supply chain. Besides, the G&S criteria have been adopted as one of the criteria for the NGB development. The message which BP wants to project is clear. BP is committed to the G&S biofuels supply, to ensure the existing biofuels can be produced in a socially and environmentally responsible way; while the incoming the NGB is environmental friendly, socially ethical and sustainable.

Chapter 6 Royal Dutch Shell in Biofuels Business

Preface

There are some similarities between BP and Shell operating in the UK regulated market under the Renewable Transport Fuel Obligation (RTFO). As one of the world six oil companies which is pursuing the next generation biofuels (NGB) development (refer appendix 7.1.1), Shell is currently supplying biofuels in the UK under the RTFO (2008).

This chapter begins with the rationales which have stimulated the business interests of Shell, to embark on the route of pursuing biofuels supply and innovation. Operating under the regulated market, the EU/UK Government have established mechanisms which help to deliver biofuels deployment and development regionally/nationally. This study has provided insights into the interactions generated between Shell and the EU/UK Government, whilst examining its response to these mechanisms instituted. Since technological change is a dynamic process, which incurs various types of expected/unexpected risk and uncertainty (R&U), this chapter also describes how Shell devised its strategy to deal with the R&U encountered along biofuels deployment and development.

6.1 Introduction

Founded in 1907, with its headquarters located at The Hague, Netherlands; Shell has been one of the global oil players, supplying fossil energy products for more than a century. Operating in more than 100 countries, Shell's expertise covers the upstream, the downstream and technology development (refer appendix 6.1.1) (Shell, 2010). Since 1970s, Shell started its biofuels business, by acting as one of the biofuels distributors in Brazil due to the effectuation of 1974 Brazilian Proalcool Programme[161], which was backed up by the vast home grown sugarcane for bioethanol production. Similar to BP, Shell started supplying biofuels in the UK from 15 April 2008 under the RTFO. Therefore, Shell has been a biofuels distributor for

161 The bioethanol use in Brazil is initiated by the Brazilian National Alcohol Programe-Proalcool since 1974. It has been in effect for 36 years (counting until 2010) by promoting the usage of bioethanol derived from sugarcane as an alternative fuel for cars.

nearly thirty-six years. Until 2011, Shell still does not manufacture biofuels, but instead buys them from international suppliers and blends them with conventional fuels. It is expected that, the NGB R&D projects would be able to produce a sustainable supply in a commercial scale, five-to-ten years from 2008.

6.1.1 Three Driving Forces for Shell Biofuels Uptakes

Shell distributed more than 6 billion litres of biofuels in 2008. Currently, Shell does not produce biofuels, but buys in[162], stores, blends and distributes the 1G biofuels for the world demand (Shell, 2008). This is because, Shell started the 2G biofuels development (wheat straw bioethanol) since 2002, but this has yet to be commercially available.

In 2007, over 80% of bioethanol was used for blending with gasoline, with the remaining 20% biodiesel being used for diesel engines. According to Shell (2009a), three-quarters of the biofuels purchased in 2007 were produced from corn/soy from the US and sugarcane from Brazil (Shell, 2009a). This was due to the competitive advantage of the US and Brazil, as the world biggest maize/soy and sugarcane producers, consequently leading to largest biodiesel/bioethanol productions. There are three driving forces which influenced Shell's decisions to enter biofuels business.

(a) The Energy Challenge

By 2050, the world will need twice as much energy as today, while regulated by many policies that allow emitting half of today's greenhouse gases (GHGs). As the global population heads for 9 billion in 2050, supplies of conventional oil and gas as the transport energy will struggle to keep up. Furthermore, the GHGs reduction will be one of the biggest challenges ever. “The world cannot support society's current habits forever. We need new sources of energy, less CO_2, and more sustainable lifestyles in energy consumptions. Biofuels cannot be left out of the mix and have the potential to be an affordable, genuinely low CO_2 fuel,” said Rob Routs-the Executive

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162 from the international market, like the USA, Brazil, Canada, South East Asia and South Africa, supplying for the UK under the RTFO.

Director Oil Sands, Oil Products and Chemicals (Shell, 29 October 2008). Due to the technical convenience provided by biofuels, particularly their capability for carbon reduction and their adaptability in the existing internal combustion engines (ICEs)/hydrocarbon infrastructure, biofuels become a vital part of Shell future energy mix[163], serving the global increasing energy demand for road transport use.

(b) Biofuels as Fuel Option for CO_2 Reduction

Since the world needs to double its energy supplies while simultaneously cutting CO_2 emissions in half, to achieve more energy with less CO_2, Shell has to conserve and diversify its energy sources, to secure the correct energy mix in preparing for future demands. "Bear in mind we need more energy, with less CO_2. Biofuels can reduce CO_2 emissions over petrol or diesel by up to 90% on a farm-to-wheels basis," said Routs (Shell, 29 October 2008). Currently, road vehicles account for nearly 17% of global CO_2 emissions and the number of vehicles on the road could increase to more than two billion by 2050 (World Business Council, 2004). Despite the future promises of electric/H_2 cars, the largest proportion of existing vehicles running on ICE will still require liquid fuels[164]. Hence, to allow the ICEs could be operating on roads, biofuels which can be blended with petrol/diesel provide an economic solution without high switching costs involved.

(c) Government Policy and Targets

Many governments in developed countries such as the EU member states are supporting biofuels development and deployment with mandated targets for renewable transport fuels. The EU Biofuels Directive (EUBD) 2003 has laid down a target of 5.75% by 2010 of biofuels application among its member states. This is further extended by the EU Renewable Energy Directive (EURED) 2009 which proposes 10% of road vehicle fuel from renewables by 2020. In the UK, this has been transposed into RTFO as a mandatory target of 2.5% in 2008/9 will rise to 5% in 2013/14. According to the Engineer of the Renewable Energy Team from the

163 Shell energy mix profile includes fossil energy: coal, oil, gas and RE of wind, solar, H_2, biofuels.
164 petrol, diesel, liquefied natural gas and biofuels blend with petrol/diesel

interview, biofuels percentage could be increased up to 10% after 2013/14. Such increase would largely depend on the political mandate, incentives, the fuel technological breakthrough[165], the G&S criteria of biofuels[166] and the availability of green cars[167] which can adopt higher concentration of biofuels use.

"Politics, economics and the environment, all of them do contribute by different degrees for biofuels (implementations) in the UK. At this moment, it is due to the policies that encourage the corporates to gain from the carbon trading. Shell distributes biofuels to meet specific government requirements in a few countries, like the UK for example. Biofuels is an energy landscape which has been directed by the policy makers. Furthermore, it is quantifiable with the biofuels in terms of percentage of greenness in the total fuel consumption," explained the Executive of CO_2 Abatement Project Team from the interview. Further commented by the Engineer from the Renewable Energy Team from the interview: "From the environment perspective, the concern of climate change as global issues has been emphasised. The EU is by far the leader in stretching their GHG reduction targets. So obviously whatever they could put their hands on (to reduce GHGs), they will strive to achieve this including a push for biofuels."

To summarise these three driving forces, Jan van der Eijk-the Group Chief Technology Officer commented: "As I see it, we are on the eve of an energy technology revolution, triggered by a number of factors. Firstly, concern about the security of energy supply. Society wants more energy sources so as to be less dependent on a limited number of energy exporting countries. Secondly, current easy oil will become exhausted in due course, already leading the industry to look at more difficult, unconventional resources. Besides, society simply expects that alternatives

165 Biofuels are currently being constrained by the technical limitation of the ICEs. World automobile manufacturers would provide warranty for biofuels which are used up to 5% only.
166 The expansion of biofuels which beyond 5% is also determined by the capability of biofuels production. Biofuels (or the NGB) should demonstrate they could be produced in a G&S manner (to comply with the Principles and Criteria outlines by respective roundtables); it does not create negative implications (as the 1G biofuels did, which rendered to the systemic risks occurrence) and it has to be environmentally and socially responsible.
167 Such as hybrids which can adopt higher concentration of biofuels, or flex-fuels cars.

will be developed in response to climate concerns.” Inevitably, biofuels could contribute a significant difference to enrich the energy mix for the road transport sector and sustain Shell's energy businesses. In securing energy supply and lowering CO_2/GHG, biofuels are one of the contemporary options, as they could be sustained in the long-term, to fulfil both the regulatory and market requirements (Shell, 13 July 2007).

6.1.2 Shell Dealing with the EU/UK Governments' Policies and Regulations

There is an increasing interest from the EU/UK governments in adopting biofuels, as a response to the concerns on fossil fuel dependence associated with energy security and GHG reductions. The EUBD (2003), the EURED (2009) and the RTFO (2008) are policies which reflect the EU/UK Governments' interests. These messages were delivered to Shell-as one of the oil companies which is actively supplying biofuels.

Both the EUBD and the RTFO have specified the annual targets which have to be attained in the overall market (for the EU and the UK market). “Shell supports action to address greenhouse gas emissions and climate change. We recognise the need for governments to reduce CO_2 in transport. Clearly, such policies have been adopted in Europe and the UK. No doubt that clear and simple government policy support will be the absolute key to the success of biofuels,” said Lauren Iannarone-the Vice President of External and Government Affairs (Webchat, 2009b). In order to commence biofuels smoothly, the incentive of 20p/litre has been adopted in the UK since 2003. This incentive brings two benefits: Firstly it helps the oil companies to sustain their biofuels sales in order to motivate the course of execution. Secondly, it maintains the retail price at an affordable level for motorists, without burdening them with the actual full cost. Further explained by Routs: “The market for biofuels today is driven by government mandates, not a price advantage over oil. The UK’s Renewable Transport Fuel Obligation requires that 5% of the UK’s fuel be made up of biofuels by 2013/14” (Shell, 29 October 2008).

To operate in the UK, Shell complies with the Renewable Fuels Agency’s (RFA)

Meta/Qualifying standards for the adoption of the G&S criteria on biofuels products and production. Routs commented: "Governments can do their part by regulating the sustainability of supply chains and creating market based incentives that reward biofuels with low CO_2" (Shell, 3 July 2008). Every month, Shell reports to the RFA under the "Carbon and Sustainability" reporting system, on information about its biofuels sales data[168]. Then, the RFA will issue the RTF Certificate for every litre of biofuels Shell supplied.

According to Shell Corporate Reports (2009a, 2010b), Shell started implementing its internal tracking systems to record information about biofuels purchased. Explained by the Quality Engineer from the interview: "Every month, we have to report to the Fuel Agency (RFA) on biofuels. We require our suppliers to submit monthly reports to us. Then we convey information on the carbon savings and sustainability issue of biofuels to the Fuel Agency. We require precise information of the biofuels source, from which country, what types of land use...almost everything wanted by the agency." Inevitably, Shell though its representation on national/international standards bodies, has been supporting the work of the European Committee for Standardization (CEN) (refer appendix 5.1.4), which is developing sustainability requirements for the development of the EURED (2009) and the Fuel Quality Directive (2009) (Shell, 2009a).

6.1.3 Shell Embarking on the Next Generation Biofuels Development

During the interview, the Executive of CO_2 Abatement Project commented: "Firstly we are looking forward to the sustainability of biofuels, which links to the social environment responsibility. Next, we want to be a leader in biofuels which will give Shell the strong leading position. Both of them provide the fundamental motivations for Shell to capitalise on the technology (biofuels)." Further explained by Peter Voser-the CEO of Royal Dutch Shell: "At Shell, social-environmental responsibility is the source of inspiration for our people. We will continue to produce efficient and

168 the quantity sold on particular month, country of origin, feedstocks, sustainability standard, land use change and CO_2 saved.

sustainable biofuels" (Shell, 13 October 2009). As explained above, the corporate social responsibility and the economic motivation are the two factors which led Shell to pursue on the NGB development.

Currently, the 1G biofuels is largely derived from food. When choosing these feedstocks, people have looked primarily to plants that can be grown to provide the largest yield. In 2007, Shell's 1G biofuels was made up of 50% corn, 27% sugarcane, 11% rape/soy beans, 5% wheat, and the remaining 7% of other feedstocks such as palm oil and sunflower oil (Shell, 2009a). Therefore, one of the objectives for the NGB R&D is to seek for feedstocks which are non-food and with high yield, yet could be produced at a lower cost. This view is supported by the Quality Engineer from the interview: "Cost is our main concern. We have to choose materials which are high in fuel (feedstocks which provide a higher yield) for our investments. The biofuels production cost is very high now. But, I think it can be reduced by technology enhancement when we do more on second or third generation. So, one day biofuels prices may compete with petroleum. I think, the second generation biofuels could be on the market in five-to-ten year time. To get there, we are investing in partnerships, targeted at technical breakthroughs and cost reduction for each of the R&D projects."

Through various types of collaboration with several biotechnology institutions (academic and commercial laboratories), Shell has the NGB developed. From the interview, the Engineer of the Renewable Energy Team explained: "Shell's interests in biofuels are focused on sustainable sourcing and to reduce greenhouse gases. Our investments in the next generation biofuels are to bring quality and cost effective products to market." Besides, the Executive of CO_2 Abatement from the interview commented: "Our researchers are working all over the world-India, Germany, the US; and there will more to come. As a global company, we take a global approach." Therefore, it is clear that, Shell's research partnerships have been cross-border collaborations, and varied according to the expertise, infrastructure capability and the geographical availability of the feedstocks[169]. The next section details an update for the NGB development projects which Shell has established with different partners.

6.2 Shell's Seven the Next Generation Biofuels Development Projects

From year 2002 to 2010, through three main types of partnerships (direct funding, joint venture-JV and strategic alliance-SA), Shell has established seven the NGB R&D projects (refer appendix 6.2) which are spreading across the globe. These projects set ways to increase the quantity of biofuels supply, to switch biofuels away from food chain, to achieve the G&S criteria, to solve the limitations of the 1G biofuels, and to comply with the regulations required by the EU/UK Government. Table 6.1 presents the summary of these seven NGB projects.

6.2.1 Shell's Latest Achievement on the Next Generation Biofuels Development

On 10 June 2009, marked an important event for Shell. Shell officially declared its wheat straw (the 2G) bioethanol, and commenced a pilot market testing in Ottawa, Canada. According to Sweeney-the Shell Executive Vice President of Future Fuels and CO_2 “From today (10 June 2009) and for a month period (until 10 July 2009), customers at a Shell service station located in Ottawa, will become the first in the world to fill their tanks with gasoline containing the 2G biofuels made from wheat straw[170]” (Shell, 10 June 2009).

169 such as wheat straw in Canada and microalgae in Hawaii.
170 Only one station in Ottawa was selected. The fuel contained 10% wheat straw bioethanol, which was produced from Iogen’s demonstration plant, named as E10.

Table 6.1: Shell's Milestones

Year	Projects Partnership	Modes of Collaboration	Projects Information	Project Types
2002, extended on 15 July 2008	Shell and Iogen	JV	Cellulosic ethanol from wheat straw, and a demonstration plant set up in Ottawa.	-Biofuels innovation -Investing in production plants
2005, extended on 17 April 2008	Shell and CHOREN	JV	BTL from forest residues and waste wood/wood chips into biodiesel, and a demonstration plant set up in Freiberg	-Biofuels innovation -Investing in production plants
2007	Shell and HR Biopetroleum: Forming Cellana	JV	Research of marine microalgae to produce biodiesel in Hawaii	Biofuels innovation
26 March 2008	Shell and Virent	SA Joint R&D	Development of biogasoline with the conversion from sugar to biogasoline	Biofuels innovation
17 September 2008	Shell with Six Universities	Direct funding	Seeking new feedstocks and new process technology	Biofuels innovation
2007, extended on 10 March 2009	Shell and Codexis	JV	Enzyme Conversion, working closely with Iogen to enhance the efficiency of enzymes used in the cellulosic ethanol production process	Biofuels innovation (catalyst)
1 February 2010	Shell and Cosan	JV	Sugarcane plantation, processing facilities	-Investing in production plants

Source: Summarised by the researcher

Local news agencies such as the Canadian Broadcasting Corporation (CBC) News (11 June 2009) ran the announcement in their news bulletin, which then created some positive reactions from the locals. John Baird-the Transport and Infrastructure Minister of Canada commented: “This one small retail station in Ottawa is one big step forward for an advanced biofuels**” (**Deutscher, 2009). The one-month pilot selling scheme has raised Shell’s profile in the biofuels market. Besides, it also provided a testbed (for market response and the actual application on road) on its wheat-straw bioethanol. Besides, this launch is also aimed to examine the actual application of the 2G bioethanol on road. Such publicity was aimed as a signal to its competitors, and to position Shell as one of the advanced biofuels producers.

6.3 Risk and Uncertainty Faced and Strategies Adopted by Shell during the 1G Biofuels Deployment

Based on the literature (refer Table 2.4.2), according to Rosenbloom and Kantrow (1982), Pearson (1991), Rosenberg (1994) and the SpecialChem report (2011), there are three R&U[171] arising from a technology deployment. Table 6.2 present the R&U faced by Shell during the 1G biofuels deployment together with strategies implemented to have these R&U resolved.

Table 6.2: Risk and Uncertainty from the 1G Biofuels Deployment and Strategies Applied to Counteract

The 1G biofuels deployment	Strategies applied
Business operations: (a) Complexity of the 1G biofuels supply chain. (b) Short-term biofuels contractual supply system.	 (ai) Shell's declaration for Social and Environmental Safeguards. (aii) Sustainable Sourcing Policy (SSP) formulation and implementation. (b) Prolong term contract and decrease spot contract.
Technology: Socioenvironmental implications (a) Food fuel competition (systemic risk). (b) Land use and Biodiversity threatened (systemic risk). (c) Ambiguity of biofuels carbon neutrality.	 (a) The NGB development (wheat straw, BTL, algae) as non-food feedstocks. (b) Control by SSP, roundtables participations and the 2G/3G biofuels R&D. (c)The NGB development due to their high carbon savings.
Technology: Technical limitation of the 1G bioethanol.	-R&D for biogasoline.
Social acceptance of biofuels.	-Utilise corporate website, and YouTube to promote biofuels, educate public about biofuels and broadcast latest information. -Utilise webcasts and webchat to answer biofuels controversy.

Source: Summarised by the researcher.

6.3.1 Risk and Uncertainty of Business Operations

During the early stage of the 1G biofuels deployment under the RTFO, Shell faced two challenges from its biofuels business operations: the complexity of the 1G biofuels supply chain, and the short-term contractual biofuels supply system.

171 business operations, technology and social acceptance.

(a) Complexity of the 1G biofuels supply chain

Previously, Shell found that it was difficult to assess its biofuels information due to the complexity of the supply chain. The usual public perception on biofuels supply chain is rather simple and straight forward as shown in figure 6.1 (Shell, 2009a).

Figure 6.1: The Simplistic Biofuels Supply Chain Perceived
Source: Shell. 2009a. pp.7.

However, in reality, the supply chain is not as simple as the diagram shown above. Some feedstocks suppliers may simply market them, without identifying the source (from which farms/country they are from). While other suppliers/traders, (usually big biofuels operators/companies) are working across different markets and could intervene some parts of the supply chain. To complicate the situation further, the chain may span across the globe involving many countries. There are known cases traced where feedstocks purchased in one country, actually came originally from another. The actual complexity of biofuels supply chain is shown in figure 6.2.

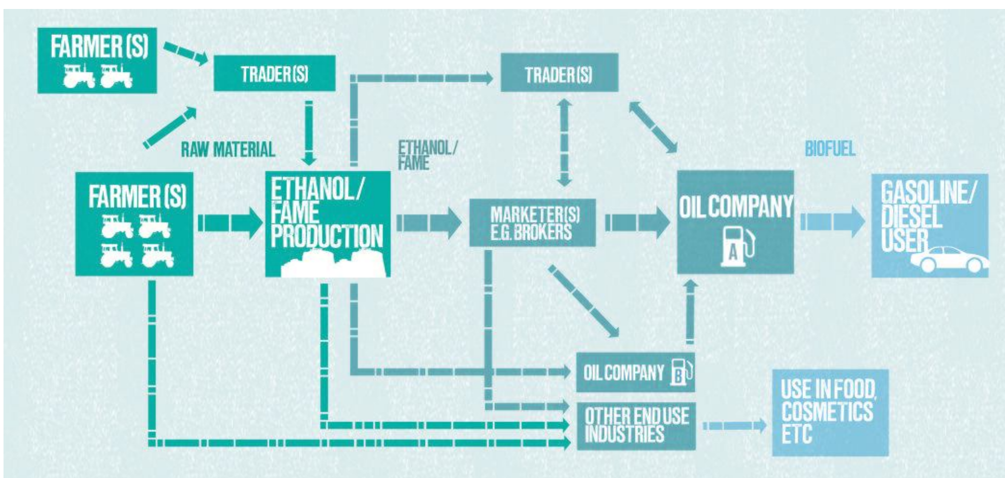

Figure 6.2: The Actual and Complex Biofuels Supply Chains
Source: Shell. 2009a. pp.7.

Consequently, there are three implications caused by the complexity of the supply chain. Firstly, biofuels feedstocks may come from many different sources/nations without proper identification. Secondly, there might have additional inputs at any point through traders, which might have been sourced from unsustainable feedstocks. Thirdly, the possibility for co-mingled storage and transportation which never could demonstrate adequate traceability. All of these are a big challange for Shell's biofuels businesses. If these challenges have not been resolved, then they would violate the Meta/Qualifying standards set by the RFA.

(b) Short-term contractual biofuels supply system

Traditionally, in order to ensure the consistency of supply, Shell has established two types of contractual supply system: “Short-term” and “Spot” contracts. Explained by the Quality Engineer from the interview: “Biofuels purchased under a short-term contract, was an agreement to purchase regular quantities for a defined period of time. Furthermore, Shell also made spot contract-a one off purchases which was handy enough to meet shortfalls and short-term spikes in demand. Obviously both (the short-term and spot contracts) have pros and cons. You have to understand, producing raw materials (biofuels), mainly depends on weather and harvest, which could affect the yield. You hardly get any guaranteed supply (in quantity) if you just depend on one (type of contract).”

Even though these two types of contract helped to stabilise the quantity of biofuels supply; yet, they also placed Shell in the insecure position to be exposed to numerous uncertainties in quality control. The Quality Engineer from the interview commented: “In many regions, information about spot market purchases can be sketchy. It is hard to know where the biofuels are made, by whom and under what conditions. Although the term and spot contracts were be helpful in stabilising the quantity, they could not guarantee the sustainability criteria of biofuels.” The complex supply chain and contractual supply system rendered a fundamental problem: limited record and traceability of biofuels supplied. The inadequacy and opacity of information, led to a higher degree of uncertainty for Shell.

Besides, the short-term contractual biofuels supply system has failed to build up a loyal supplying relationship. This can make biofuels very difficult to be verified on the types of environmental and social conditions the feedstocks are grown. Therefore, if the biofuels' information is remain unknown, this may cause Shell fails to report to the RFA. In order to overcome these R&U of business operations, Shell adopted three strategies: Firstly, the corporate mission statement to declare that Shell is interested only at G&S biofuels. Secondly, the Sustainable Sourcing Policy (SSP) formulation and implementation, and lastly to reduce the use of the spot contract for biofuels supply.

6.3.1.1 Shell's Corporate Mission in Shaping the Green and Sustainable Biofuels

Shell declared its stand openly/clearly through various corporate medium[172], which emphasised its commitment and interest at G&S biofuels. Explained by the Biofuels Officer from the interview: "Shell determines its working practice to ensure that biofuels purchased for blending are produced in a sustainable way." The corporate mission declaration brought two benefits. Firstly, solving the R&U of business operations (discussed at 6.3.1) and the socioenvironmental concerns[173]; secondly, shaping Shell's green business image. According to Routs: "We have an obligation to manage today's biofuels responsibly. So we have been establishing social and environmental safeguards among our biofuels suppliers. We are trying to ensure sustainable sourcing, and working hard to influence others in the industry to raise their own sustainability standards. Sustainability is central to everything we do. It is written into our business principles, the backbone of the way we act. It motivates much of our R&D, and it shapes many of our policies and strategies: from our advocacy for government caps on CO_2, to our investment in the next generation biofuels," (Shell, 29 October 2008).

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172 Through its annual corporate report on biofuels[1,2], corporate policy[3,4] and through corporate website[5]
Source[1]: Shell. 2009a. Source[2]: Shell. 2009b. Source[3]: Shell. 2007a. Source[4]: Shell. 2006. Source[5]: Shell. 2008.

173 Social and environmental safeguard of sustainability clauses defined by Shell includes: feedstocks and biofuels which do not linked to the violation of human right like forced/child labours, biofuels which are not compete with food, not planted in high value areas (food farm, jungles, forests, any preserved areas, or any land conversions from high biodiversity), not polluting the land or a water source (minimise the use of fertilisers) and allows traceability (Shell, 2009a).

6.3.1.2 The Sustainable Sourcing Policy Formulation and Implementation

In 2006, Shell set up a Biofuels Sustainability Team and appointed a few number of Biofuels Sustainability Compliance Officers (BSCOs), to develop a strategy for the sustainable sourcing of biofuels. These BSCOs were assigned to develop the Sustainable Sourcing Policy (SSP)-a corporate policy for G&S biofuels operations (refer appendix 6.2.4).

In August 2007, the SSP was formulated. It explains Shell's corporate mission and outlines Shell's commitments to work with governments [174] and its suppliers, to incorporate G&S clauses into supply contracts. In 2008 (during the RTFO effectuation), Shell established a more manageable biofuels supply system, which allowed for a higher degree of control of its biofuels supply chain. With the manpower (BSCOs)[175] in place, the biofuels business which guided by the SSP, and the supply contracts which incorporated the SSP; all of these were acting as the control mechanism for Shell to achieve its G&S biofuels business. The Biofuels Officer from the interview commented: “With SSP, we are working closely with our biofuels suppliers. We communicate with EEA (European Environment Agency), Roundtables[176] members, policy makers and members in the industry (peers, the oil companies, the biofuels suppliers) to promote robust global biofuels standards for biofuels sustainability.” “The head office has appointed a team to visit overseas like Brazil, USA and South Africa to assess our suppliers from time to time. We visit their farms and processing plants, to make sure the requisite sustainable sourcing of biofuels can be obtained. The assessment is to examine the farms and the production plants which must comply with Shell's terms and conditions bound by the supply contract incorporated with the sustainability clauses (SSP). After that, we will report

174 the EU Government, the UK Government, as well as any government which Shell is operating within that country.
175 BSCOs are working as assessor and auditor, ensuring the biofuels farms operated sustainably (by visiting to the farm), and communicating with the farmers/producers/traders/suppliers to comply with the Shell's SSP requirements.
176 Shell is a member of Roundtable for Sustainable Biofuels (RSB), Roundtable on Sustainable Palm Oil (RSPO), Roundtable for Responsible Soy (RTRS) and Better Sugarcane Initiative (BSI).

the assessment in the company's sustainability report.”

Inevitably, the SSP plays an important role in controlling Shell's biofuels supply chain. In September 2008, more than half[177] of the biofuels Shell bought were covered by contract clauses while the remaining 25% is working towards the compliance. Paloma Berenguer-the Sustainable Development Manager explained: “We are actively working to cover the rest of our volume (25%) with our sustainability contract clauses” (Webchat, 2009b). Furthermore, in order to validate the internal governance with its related records, Shell sought an independent auditor[178] to verify its monthly biofuels reporting information to the RFA.

To conclude how Shell is managing its biofuels supply chain, Berenguer commented: “In order to ensure a sustainable biofuels business, we must lay the foundations for sustainability. We established our own policy (SSP), and criteria place in our contract, to ensure our suppliers are not engaged in; for example, harmful deforestation or exploitative labour practices. We have also appointed a sustainability compliance officer and begin formal assurance of our standards. We have created a reporting system on our activities and track record so far in this specific area” (Webchat, 2009b). Evidently, Shell's internal BSCOs[179], the SSP oriented supply contracts, together with the KPMG and ProForest audits, all of these were complementing each other to provide a higher accountability and validity in biofuels reporting system.

177 By the end of 2009, 56% of the biofuels Shell purchased (by volume) were from suppliers who have signed up in full to its sustainability clauses which appeared in their supply contracts. Shell purchased a further 19% from suppliers who have partially adopted its clauses and are moving towards full implementation. This means 75% of the biofuels by volume, at the end of 2008, were covered by Shell’s contractual sustainability clauses (Shell, 2009a).

178 Shell has appointed KPMG, who has international experience in sustainability biofuels assurance. Besides, Shell has also appointed ProForest-a consultant that specialises in practical approaches to sustainability biofuels. They are helping Shell with technical advice in developing sustainability biofuels businesses (Shell, 2009a).

179 regular visits to the biofuels plantations, engaging with the biofuels suppliers on the SSP execution, coordination between Shell and suppliers, and reporting their findings to senior executives.

6.3.1.3 Prolonged the Term Contract and Decreased the Spot Contract

The spot contract has been terminated, while a longer-term contract (three-to-five-year) is awarded to the eligible biofuels suppliers who can comply with the SSP sustainability clauses. The Biofuels Officer from the interview explained: "Nowadays, we do not purchase biofuels from the spot market. They do not have adequate information that we required. Before we decide our supplier, we will ask for (supplier's) company profile, to understand its background. We also ask our potential suppliers to fill in supply chain questionnaire, to help us assess the potential risks before we decide whether to enter into new contract with them." Shell has incorporated sustainability clauses into new supply contracts since September 2007 (Shell, 2009a). Further explained by the Biofuels Officer from the interview, the new contract with the sustainability clauses (as outlined by the SSP) provides a more secure business prospect for farmers, producers and traders. Only suppliers whom can comply with the sustainability criteria outlined, and have the capacity in producing more consistent supply, then contract would be awarded.

6.3.1.4 The Sustainable Sourcing Policy Execution towards the Renewable Fuels Agency Compliance

Both the Quality Engineer and the Biofuels Officer from the interview mentioned the RFA's Meta and Qualifying Standards obligated under the RFA. According to the Biofuels Officer, Shell not only emphasised these two standards in its internal business operations, but it also has extended the criteria to its suppliers through the SSP implementation. This was to ensure the whole value chain-starting from the farm to the petrol kiosk, every activity complies with the G&S criteria. The SSP oriented supply contract has specified that, adequate/accurate biofuels information must be reported every month to Shell. After that, the information gathered from the various suppliers is used to report to the RFA under the "Carbon and Sustainability" reporting system. If any of Shell suppliers breaches the terms of the contract, or violate any of the sustainability clauses of the SSP, the supplier contact will be terminated.

Explained by the Procurement Executive from the interview: “Contract is a form of responsibility sharing, in a legal way, which ties Shell and the biofuels suppliers together, in order to ensure the sustainability biofuels process-from the early stage of production until they reach the market. We review their (suppliers) progress on a regular basis. They have to report to us every month. We have the right to terminate contractors who violates the terms of the contract.”

The Procurement Executive from the interview commented: “We need to choose whom we want to do business with. We have a lot of suppliers who are international players and many of them have the credibility of supplying clean and sustainable biofuels. This contract is not just for the sake of business, the social responsibility is important for us too. If they (the suppliers) want to supply to Shell, they must commit (the sustainable criteria) to work with us. The contract has many terms and clauses which address the environmental concerns of biodiversity, sustainability, environmental friendly and social well being. We have introduced environmental and social safeguards into our contracts, and we will be continuously tracking the performance of our suppliers.”

To date, Shell purchases feedstocks globally from approximately 100 biofuels suppliers (Shell, 2009a). From the interview, the Procurement Executive explained: “It is not easy to comply with the SSP and the contract sustainability clauses. Choosing the best (whom could comply with the sustainable criteria) is not easy too. But this is not impossible! If you can get the good players, then you are confident to play the game well. We could never take in those who are not fit (cannot comply with the sustainable criteria), and we are playing the game now.” As a result of the implementation of the SSP and long-term supply contract, the RTFO’s first interim quarterly report reported that Shell had one of the highest levels of data capture, and was the only major oil company to exceed the target for carbon savings (RFA, 2008).

6.3.2 Risk and Uncertainty of Technology: Social and Environmental Implications by the 1G Biofuels Deployment

Shell through its Corporate Report (2009) admits, “Biofuels are no silver bullet”. This means that biofuels could never provide the perfect solution and have total effectiveness in solving all prevailing problems as expected. Even though biofuels contribute to the GHG/CO_2 reductions, their carbon neutrality and their adaptability into existing ICEs/hydrocarbon infrastructure; there are a range of issues which need to be addressed concerning with their use and the consequences of mismanagement.

Firstly, the 1G biofuels can compete with food crops for its market share, either to feed mouths or to power vehicles. Secondly, for the available land, the cultivation of biofuels feedstocks has resulted in land competition for food crops and fuel crops farming. Thirdly, destruction of valuable/ high biodiversity areas like forests, displacement of local communities and unnecessary pollution (water/land pollution due to fertilizers used in growing biofuels crops) could happen if biofuels farming has not been managed appropriately. Fourthly, the validity of carbon neutrality since the CO_2 performance of the 1G biofuels varies depending upon the feedstocks and the activities involved along the supply chain.

From the interview, the Executive of CO_2 Abatement Project commented: “Frankly speaking, I was at some point buying into the idea (of biofuels) after listening to the famous venture capitalists’ idea about biofuels. However, after seeing that basic food commodities have gone up tremendously throughout the years, I am changing my supportive view about it. If I am not mistaken, the current dedication of food crop to biofuels has already caused so much of the food shortages and price increases. However, the current biofuels have not contributed to even 5% of global petroleum consumption. The previous US government was strongly encouraging on biofuels, as it was perceived that the oil wealth would be transferred from Middle Eastern countries to their farmers.”

It was rather a surprise since the Executive was not convinced with the potential of biofuels at the early stage, due to the emergence of systemic risks which rendered a food-fuel competition and threatened biodiversity. The media/social movements/environmentalists have amplified biofuels negative implications openly which eroded public confidence in the UK. It was not until a second visit, in December 2009, that the Executive had his view changed on biofuels. "Reading more and knowing more, the scientific evidences are rather convincing. I could not ignore the fact of our Ottawa's pilot product," said the Executive of CO_2 Abatement Project. Therefore, an early prejudgment of biofuels, without adequate knowledge would result in the misconception of biofuels. Due to the international/national media/social movements/environmentalists have amplified (possibly exaggerated) the systemic risks, repetitively, for a period of time; it will take a long time to have the deep-rooted preconception/misconceptions changed.

6.3.2.1 Dealing with Food-Fuel Competition

During the early stages of the 1G deployment under the RTFO, the British Public felt the pressure of food price increased. From the interview the Engineer from the Renewable Energy Team explained: "One problem of conventional biofuels is that, they use food crops. If a biofuels business needs to be expanded, then food crops for biofuels are a no-no! That is why the non-food biofuels are needed. No matter how I look at it (biofuels), besides the fact that it is renewable, it's still not economically viable at least for the time being. Of course you will hear most people disagree with this particularly the oil companies who vehemently denied that they were using the food crops for biofuels." This few was further supported by Routs: "Three or four years ago, we saw that this technology, whereby food crops are converted, would have an impact on food supplies. You now see this is happening. We do play a major role in the supply chain, particularly in the USA and Brazil. But we do not want to get involved in a big way in the first generation production. I have no wish to hear in ten years time that the oil industry is the cause of hunger in the world" (Shell, 24 August 2007).

"In the meantime, we cannot just sit back and wait for the second generation biofuels to come good. Instead, we work hard with industry and with governments to raise the sustainability standard of the currently available biofuels," commented Routs (Shell, 29 October 2008). From the conversation with the Engineer from the Renewable Energy Team, and reading on Routs' interview, both agreed that, the 1G biofuels, which is derived from food is not sustainable. These foodcrop biofuels, not only diminish human rights on food, but they also have their limitation that do not help Shell to scale-up the production capacity to meet the growing demand. Conversely, the NGB can provide a higher capacity of production[180], and changing the fuel from food to non-food feedstocks fulfils what is now a mandatory requirement. Currently, Shell has three projects[181] focusing on the non-foodstock NGB development

6.3.2.2 Dealing with Land Use and Biodiversity Threatened

One of the issues relating to biofuels is the direct/indirect land claims for biofuels, for example causing farmers and cattle breeders to invade deeper into the Amazon jungle (Butler, 2007). This has caused further jungle clearances in order to accommodate either new biofuels plantations; or new food plantations as the existing food farms have been converted to biofuels plantations (Hirsch, 2007; BBC, 29 June 2007). Commented by the Engineer from the Renewable Energy Team from the interview: "The first generation biofuels puts more pressure on the land use. We are using more land than ever for the fuel crops, chopping more trees to give way, clearing more land, destroying more flora/fauna, and polluting more land. These are the consequences of unplanned land use." In order to minimise the impact of land use for biofuels farming, Shell has implemented three strategies: SSP execution, roundtable participation and the 2G/3G biofuels development.

(a) Control by the SSP

Shell is currently supplying its 1G biofuels under the RTFO which is sourced from the international markets. As one of the main commercial biofuels suppliers, Shell has caused a direct impact on land used in the biofuels producing countries. Today

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180 due to the abundance of biomass found naturally, or from agriculture residues after the fruits have been harvested.

181 Shell-Iogen (wheat straw), Shell-Choren (BTL), and Shell-HRBiopetroleum (Algae)

around 1% of the world's total arable land (approximately 14 million hectares) is given over to biofuels production. However, it is estimated that by 2030 this could more than triple, according to the International Energy Agency (IEA) (Logan, 2007). Commented by Voser: "The IEA thinks biofuels might account for 11% of road transport fuel by 2030. Today's biofuels will be critical in reducing the carbon intensity of road transportation over the next decade. Yet we also need to manage the social and environmental challenges of biofuels" (Shell, 26 November 2009).

Further supported by the Biofuels Officer from the interview: "At Shell, we are guided by the SSP. We are investigating ways to identify and using idle land that could be used for growing biofuels feedstocks, without over stretching the farm lands or causing more jungle clearance. In late 2007, we sent all our suppliers our SSP, to be incorporated into new and renewed contracts. The SSP sustainability clauses include a specific clause regarding land use change." Strengthend by the SSP, Shell requires it suppliers to ensure that their biofuels supplies are not sourced from areas of high biodiversity value. Besides, the sustainability standards being developed by multi-stakeholder groups at different roundtables also have such requirements on good agriculture practices in order to minimise the land use implications.

(b) Invitation for Local Government Participation in Roundtables

To date, gaining data to measure the instances of direct/indirect land use change remains a challenge for Shell, as it does not have the capability to have these data quantified and monitored continuously. This is because, Shell is purchasing biofuels on the international market. These biofuels feedstocks are not grown on Shell's own plantations/territory which Shell has full control. From the interview, the Procurement Executive commented: "Even though the supply contract (with SSP) is utilised to manage our suppliers, but we could not supervise nearly 100% of our suppliers on their daily operations. It is impossible to be 100% confident that our supply contract clauses are awalys being adhered to. We hope that the domestic governments can get involved. They can, for example, regulate the marginal land used for biofuels crop growing towards proper land use and planning."

Explained by Berenguer on the Webchat (2009b): “The best way to avoid indirect land use change is by yield improvement (through the NGB development), and to encourage producers to expand on marginal/idle land via domestic policy incentives, and practice good government land planning at the domestic authority. There is still a lot of work that need to be done, to define marginal/idle land from an environmental and social perspective. We are engaging with experts from various scientific institutions on this topic.” Since then, Shell has been working on this specific issue (the definition of marginal/idle land) through biofuels roundtables, in order to bring the isses onto the agenda and communicate with the domestic governments.

The Biofuels Officer from the interview agreed that the most effective control on land use, falls within the domestic authorities. The local authorities can adopt internationally sustainability criteria on land use, or promote the transparent and comprehensive land planning policies. Berenguer from the Webchat (2009b) further commented: “We have pledged our support to an international multi-stakeholder coalition, which is seeking to enforce a moratorium on rainforest and peat land clearance associated with the expansion of oil palm plantations in South-east Asia. We also support the actions carried out by the coalition working on soy moratorium in the Brazilian Amazon. The sustainability standards (such as the Roundtable on Sustainable Palm Oil and the Roundtable on Responsible Soy) which we support have principles and criteria (and auditing systems) to ensure that crops for biofuels and other end users are not grown on land recently cleared of high conservation rainforests”.

Apart from setting direct communications with the local government (where biofuels are sourced), Shell participates in different roundtables and engages in discussions about the land use issues within these roundtables. The efforts from roundtables resulted in the land use concern, to be formally formulated as one of the “Principle and Criteria (P&C)” (refer appendix 5.3.2), which guides related stakeholders on better land use and good agriculture practices.

(c) The 2G/3G Biofuels R&D

By switching from food to non-food biofuels through the NGB development, is one of the strategies which Shell has implemented in order to achieve a sustainable biofuels business. Taking the example of wheat, after the grains have been harvested, the agricultural residues such as stalk and leaves could be used to produce the 2G biofuels. Besides, Shell is also embarking on the 3G biofuels. It is currently working with HR Biopetroleum on marine microalgae for biodiesel production.

Agricultural residues are by-products which do not compete with food and land. Meanshile, microalgae is a potential source of biodiesel because it can grow rapidly and is rich in oil. Furthermore, microalgae do not compete with food crops, thereby reducing the need for fertile land and fresh water. The water-borne microalgae need sea water, sun and CO_2 in order to produce vegetable oil through photosynthesis (Broere, 2008). Through confined pond/sea farming techniques would have minimal impacts on the land use and a low fresh water footprint. It could also be possible to grow microalgae in a bioreactor-that could be located in areas which are unsuitable for agriculture such as deserts or coastal land.

6.3.2.3 Dealing with Ambiguity of Biofuels' Carbon Neutrality

There are conflicting reports questioning the capability of biofuels in GHG reductions. In reality, the activities involved in producing biofuels-if not well managed, may end up using more energy in the process/production cycle that causing more GHGs/CO_2 emissions. The Executive in Shell CO_2 Abatement Project from the interview explained: “Today’s bioethanol and biodiesel (feedstocks) are certainly not all the same. Some have a very good CO_2 footprint compared to the conventional fuel, like sugarcane ethanol produced in Brazil; while others are not so good.”

The Biofuels Officer from the interview added: “I am convinced we can make biofuels work without destroying food and forests. Not all biofuels are created equal. There are enormous differences in what’s used to make them and how much CO_2 is emitted in their production processes.” The Quality Engineer from the interview gave some examples of this difference in biofuels. He explained that a corn ethanol produced from America emits around 10-30% less CO_2 than petrol on a well-to-wheels cycle versus a farm-to-wheels cycle, whereas Brazilian sugarcane ethanol emits up to 90% less. This highlights the differences between the various biofuels feedstocks used in contributing to the carbon saving from the process cycle.

According to Luis Scoffone-the Vice President Alternative Energies at Shell International "Ethanol derived from sugarcane has a number of benefits. It has a good farm-to-wheels CO_2 footprint. This is partly because the waste (bagasse) can be used to power the conversion process" (Webchat, 2009b). The Engineer of the Renewable Energy Team from the interview commented: "As the research goes by, biofuels are getting better. They have better energy efficiency, lower in CO_2, and are more sustainable. We support biofuels which provide the best combinations of the highest energy density and the lowest CO_2. Sugarcane is a good example for the current business. Our next generation biofuels will be improved and make the biofuels even better."

Routs commented: "We understand that the energy costs from farm-to-wheels should be taken into account, as well as the carbon emission along the process of producing biofuels. This is one reason why we have introduced contractual clauses and SSP with our suppliers to assess any potential sustainability risks in our biofuels supply chain" (Shell, 29 October 2008). The factors which determine carbon neutrality of biofuels rely on the types of feedstock and the activities along the value chain. Shell is focusing on the 2G biomass and the 3G microalgae biofuels, which promise higher carbon savings. Besides, the adoption of the SSP sustainability clauses in supply contracts would guide the activities along the value chain. Both strategies have the potential to reduce the carbon footprint on a farm-to-wheels.

6.3.2.4 Dealing with the Technical Limitation of the 1G Bioethanol

The current low blend mixture of bioethanol within a range of 5-10% is suitable for the existing hydrocarbon distribution infrastructure and the current ICEs. However, once a higher concentration of bioethanol is required (for example E85 which constitutes 85% of ethanol), not only will the distribution infrastructure required to be modified, but also vehicles will need to be changed as well. Such a change would involve a massive switching cost. According to Sweeney “The technical properties of today’s 1G bioethanol pose some challenges to a widespread adoption. Our fuel distribution infrastructure and vehicle engines are being modified to deal with higher percentage of bioethanol, such as E85 or pure bioethanol. But new fuels such as Virent’s biogasoline with characteristics similar to petrol is promising” (Shell, 26 March 2008).

Shell and Virent announced a joint R&D project to convert sugars directly into biogasoline (refer appendix 6.2d). Virent's technology, patented as “BioForming” uses catalysts to convert sugars into hydrocarbon. Conventionally, sugars have to be fermented into bioethanol and then distilled. Compared with bioethanol, biogasoline has a higher energy content and delivers better fuel efficiency. It can be used in a pure form, or blended seamlessly with petrol. Biogasoline has the potential to eliminate the need for infrastructure modification, as well as to sustain the current ICEs use. The chemical properties of biogasoline are similar to petrol. If biogasoline could be commercially produced, this then will be one of the most important technological breakthroughs.

6.3.3 Risk and Uncertainty of Social Acceptance of Biofuels

Although biofuels are relatively new to the British public, they are not new to Shell, since Shell has been operating bioethanol in Brazil for more than three decades. In order to help creating social acceptance of biofuels, Shell takes on the responsibility to disseminate its biofuels information to the public, which not only promotes its own biofuels businesses (R&D, partnerships and products) but also builds the public acceptance towards Shell’s biofuels products.

6.3.3.1 Building Social Acceptance through Corporate Website

In order to explain and promote biofuels, Shell set up a section covering Biofuels[182] on its website. The website is rather straight forward, with five sections to explain: what biofuels are, provide information about the 1G biofuels, explain Shell's SSP, discuss the NGB and finally share the press releases on various Shell biofuels projects. The website presents collective information about biofuels. It provides simple and easy to understand information about biofuels (the 1G, the 2G to the 3G) and disseminates this information[183] to the general public in order to help built public acceptance of biofuels.

In general, the website is designed to provide/disseminate general information about Shell's biofuels development and related business activities. The information is general and is aimed at the target audience where the specific/scientific knowledge of biofuels is not required to understand the materials further. To date, Shell is the first oil company that has created its own YouTube channel[184], and utilises it as a 24/7 broadcasting media channel. Compared with its website, the informational videos found in its YouTube channel are more comprehensive and addresses various issues (not only biofuels, but other technologies) and introduces Shell’s operations in RE generation and current fossil energy. The YouTube channel has become a new/modern media outlet for Shell.

6.3.3.2 Utilising Webcasts and WebChat to Respond Biofuels Controversy

In the UK, a strong debate arouse over food-fuel competition, food price increased, biodiversity damaged due to systemic risks, all of which was fuelled by the broadcasting media and the newspapers from January 2008 to September 2008. This

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182 Shell. 2008. Biofuels. [Online]. Available at: http://www.shell.com/home/content/aboutshell/our_business/fuels/biofuels/biofuels.html

183 From this website, there is a link which will direct to another new website titled Answer Column aimed, to educate public about biodiesel. This can be found on Shell. 2007d. Answer Column. [Online]. Available at: http://www.shell.com/home/FrameworksiteId=rotellaen&FC2=/rotellaen/html/iwgen/ask_our_expert/2008/zzz_lhn.html&FC3=/rotellaen/html/iwgen/ask_our_expert/2008/answercolumn_Q9_2008.html

184 Shell YouTube. 2009a. [Online]. Available at: http://www.youtube.com/user/Shell

nine-month period saw the duration before and during the effectuation of the RTFO in the UK. This constant almost daily media coverage caused a major reduction in public confidence on biofuels adoption.

In order to counteract all this negative publicity, Shell published two webcast speeches (relating to biofuels) on its corporate website. The speakers were highly positioned and respected within the organisation/industy with the hope that the views/comments would ally the fears of the general public. Firstly, on 13 June 2007, a webcast speech with van der Eijk-the Group Chief Technology Officer was broadcasted, aimed at discussing the renewable energy prospects. Then, on 29 October 2008 a Biofuels Debate[185] with Routs-the Executive Director was held to explain the current biofuels issues and challenges. Next, on 7 April 2009, Shell invited to interested parties to participate in two live webchat sessions[186] chaired by Sweeney and other five members[187]. This was aimed at any individuals who were either concerned about the systemic risks (that had been publicised by the media) or individuals interested in Shell’s biofuels business.

Interested participants were required to pre-register for the webchat sessions and given two ways of asking questions: Firstly, questions could be submitted during the registration process for the webchat broadcast; or alternatively questions could be posted on-line during the live chat. These webchats showed the proactive approach taken by Shell, and demonstrated that a major oil company like Hell was willing to discuss with the general public their concern (on systemic risks), and to be open about their own business as wall as their R&D into the NGB. By holding the webchat, Shell not only promoted its biofuels business, it also strengthened Shell's

185 Shell. 29 October 2008. Q&A on Biofuels. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/speeches/2008/routs_biofuels_debate_29102008.html

186 The Webchat session took place on 7 April 2009. First session was at 7am-8am BST, with 44 questions being answered. Second session was at 4pm-5pm, with 60 questions being answered.

187 The Webchat session was chaired by Sweeney, together with other five members: [1]Paloma Berenguer: Sustainable Development Manager, [2]Lauren Iannarone: Vice President of External and Government Affairs, [3]Angus Gillespie: Vice President of Strategy, [4]Mike Goosey: Manager Biofuels R&D at Shell, [5]Luis Scoffone: Vice President of Alternative Energies at Shell International.

green image. The date set for the webchats was nearly a year after the introduction of the RTFO, and six months after the British media put a pause on the biofuels issues[188].

There were two reasons why Shell scheduled the webchat programme for nearly a year later. Firstly, Shell wanted to wait for a more appropriate time before having the open debate. It was Shell's strategy to let the current controversial and media hype cool-down before Shell picked up the related issues and responded accordingly supported by scientific facts and evidence. If the webchat was carried out during the height of the controversy and debate, there would have been higher possibility of social rejection.

This was because, the messages given from the webchat might not be able to reach to the public effectively; therefore the efforts and resources invested by Shell would be wasted. Besides, if the webchat was launched during the height controversial period, it might be abused as a platform for reflecting the emotions of the public, rather than a genuine discussion held between the public and the Shell representative. The latter date also allowed Shell to have itself well-prepared before facing the public. The webchat broadcasted on 7 April 2009, was also utilised as a platform to promote the 2G wheat straw bioethanol, which was planned to be test marketed in Ottawa on 10 June 2009. Under these circumstances, the result of the broadcast was far more beneficial in restoring public confidence in biofuels. The outcome of the webchat has given Shell an added confidence and respect in answering most of the questions raised and defended its commitment on G&S biofuels.

6.3.3.3 Balancing the Business, Environment and Sustainability Commitments

Two months after the introduction of the RTFO, due to the systemic risks were amplified by international/national media, social movements and environmentalists;

188 It began on 16 September 2008, with the Lehman Brothers filing for bankruptcy, which marked the beginning of world financial crisis 2008 (BBC, 16 September 2008).

Ruth Kelly, the previous UK Secretary of Transport declared, UK government's decision to slow down biofuels expansion in the UK. The UK Government amended the RTFO targets, but did not abandon biofuels policies altogether. This decision restored some confidence to the oil companies which were pursuing biofuels business supply and R&D.

From two interviews: “Since the beginning, we knew that the conventional biofuels (1G) is not sustainable. We strongly believe that the second generation biofuels is the right technology, and we have made tremendous progress on our cellulosic bioethanol,” said the Executive of CO_2 Abatement Project. “I think that is a right move. We need to send out the correct message about sustainable biofuels. Since the 1G biofuels has pressured society and caused such disputes, it was good to have the progress slow down, at least to comfort and rebuild the social acceptance of biofuels. In fact the food-derived 1G biofuels is a transition technology, and the expected biofuels which are clean, green, sustainable and non-food will be presented from the second generation onwards,” said the Quality Engineer.

The RTFO target change did not impact on Shell’s business operations. Shell continues its biofuels business and carrying on its role as the 1G biofuels supplier while embarking on the NGB developments simultaneously. In order to manage its internal business operations, the SSP is utilised to control the existing biofuels supply chain and to ensure the G&S biofuels are sourced within its contractual-operations. Shell's is confidence that the 2G biofuels is the right way forward. Shell is working forward to influence the wider biofuels industry[189] and in shaping sustainability standards. It is clear that the sustainability challenges related to biofuels production cannot be tackled alone.

According the Biofuels Officer from the interview: “We already buy and distribute a lot of biofuels today to meet the government requirements around the world. We

189 The business players within the biofuels industry are biofuels farmers, processors, traders and supplier and other oil companies.

participate in developing industry sustainability standards for the supply chain, with organisations such as the Roundtables on the development of robust standards which can be implemented on the ground." Shell participates in the Roundtable for Sustainable Biofuels (RSB), the Roundtable on Sustainable Palm Oil (RSPO), the Roundtable on Responsible Soy (RTRS) and the Better Sugarcane Initiative (BSI).

These Roundtables are entirely voluntary, but are influential enough to ensure that the mechanisms are introduced within; which ensure the G&S standards are being followed by members. This is because these roundtables have robust auditing and monitoring process. "Shell has been advocating governments to tie biofuels mandates to CO_2 performance and sustainability standards. We can see the EU Renewable Energy Directive (2009) and the UK RTFO (2008) are moving in this direction. This is critical to ensuring we get the best performing biofuels (from CO_2 saving and sustainability perspective) for the market. In addition, the UK RTFO is leveraging the good work of the voluntary roundtables (such as the RSPO, RTRS and BSI) by recognising them in their legislation," said Berenguer (Webchat, 2009b).

Further from the corporate report 2009b, Shell is building on its long-term collaborative partnership with the International Union for Conservation of Nature (IUCN)[190] in order to exchange knowledge and expertise. The IUCN's experience is in managing species and ecosystems, which could help Shell to address conservation and livelihood risks and opportunities in its decisions on biofuels operations and business expansions. Mentioned by Routs on the IUCN, "Obviously we are keen to look into any way that we can help with reducing CO_2 emissions and building sustainable biofuels. We are continually working with governments and industry to

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190 IUCN helps the world find pragmatic solutions to environmental and development challenges. It supports scientific research, manages field projects all over the world and brings governments, NGOs, UN agencies, companies and local communities together to develop and implement policy, laws and best practice. Founded in 1948, it is the world's oldest and largest global environmental network, a democratic membership union with more than 1,000 government and NGO member organisations, and almost 11,000 volunteer scientists in more than 160 countries. IUCN's work is supported by over 1,000 professional staff in 60 offices and hundreds of partners in public, NGO and private sectors around the world. The Union's headquarters are located in Gland, Switzerland.
Source: International Union for Conservation of Nature. 2009.

do that” (Shell, 29 October 2008).

6.4 Risk and Uncertainty Faced and Strategies Adopted by Shell during the Next Generation Biofuels Development

6.4.1 Driving Forces for Shell's the Next Generation Biofuels Development

Based on the three driving forces which led to the commencement of the 1G biofuels (discussed at 6.1.1), currently, Shell is currently focusing on the NGB developments, which these NGB must comply with the G&S criteria, and must be able to fulfil the mandatory targets specified by the policy makers (on the EUBD 2003 and the RTFO 2008). Besides, the NGB has to be efficient and cost-effective to ensure its viability for commercial scale production and the ability to build up capacity before supplies commence.

Today's world biofuels is just the start, the business prospect is promising, as the biofuels application is not only just taking place in the UK and other member states in the EU. Other non-EU nations such as New Zealand, Australia, Japan, Canada, China and India, are gradually adapting biofuels for their road transport use. Supported by Jorma Ollila-the Chairman of Royal Dutch Shell “More than 50 countries are developing or have renewable fuel mandates. The EU for example, insists that 10% of road vehicle fuel comes from renewable sources by 2020” (Shell, 23 October 2009). As such, biofuels could grow from just 1% of the world’s transport fuel mix today to as much as 7–10% over the next few decades. In 2008, Shell quadrupled its rate of investment in biofuels and aims to build a significant biofuels business in the next ten years (Shell, 2009a).

Comments made during the webcast (2007, 2008): “We are now spending USD1.2 billion on technology, and that comprises the costs of generating options, developing technology and testing prototypes,” said van der Eijk (Shell, 13 July 2007). “At Shell, we see ideas and innovation as the lifeblood of our business. At USD1.2 billion in 2007, our R&D spending is the highest of any of the oil majors. Biofuels from straw, wood-chips or microalgae, we are working on all these. In the end, I want to see Shell builds a low-carbon biofuels business based on sustainable sources. It could take another ten years and require technical and commercial breakthroughs. But we are determined to get there," said Routs (Shell, 29 October 2008).

Shell's biofuels strategy is rather an ambitious leap into the NGB development. Based on the literature (refer Table 2.4.1), there are three R&U[191] arising during a technology development. Using the theories advocated by Rosenbloom and Kantrow (1982), Pearson (1991), Rosenberg (1994), the researcher has identified various strategies which Shell has adopted to deal with them. As shown in Table 6.3, these are the current R&U of the NGB deployment together with the strategies implemented.

Table 6.3: Risk and Uncertainty from the NGB Development and Strategies Applied to Counteract

The NGB development	Strategies applied
Innovation process -Beyond Shell's institutional knowledge and capability at the NGB development and production.	-Shell established various partnerships with (commercial and academic) biotechnology institutions for: (i) The NGB feedstocks and process technology development. (ii) The NGB R&D and production facilities construction.
Technology -Limitation of the NGB biofuels to meet future demand.	-Diversification of the NGB R&D to scale up the future supply.
Social acceptance of the NGB.	-Utilise corporate media in promoting the NGB. -Testing 2G biofuels on motor racing event for their technical performance and to gain market confidence.

Source: Summarised by the researcher.

6.4.2 Dealing with Risk and Uncertainty of Innovation Process: Shell Established Partnerships with Biotechnology Institutions

Like most of the major oil companies, currently, Shell does not manufacture biofuels but instead buys biofuels on the international market (through its approximately 100

191 innovation process, technology, and social acceptance.

biofuels suppliers) and blends these into transport fuels, before selling in the UK market. There are two R&U faced by Shell. Firstly, the profound biofuels technology has challenged Shell's existing institutional knowledge on the NGB development. Secondly, the incapabilities/inability of Shell to produce the NGB on an industrial scale. This is because Shell's existing infrastructure is for fossil fuels extractions and refineries. Therefore, going from oil/natural gas mining to biofuels farming, this has created a major challenge for Shell. Shell is therefore collaborating with various cross nations biotechnology institutions (commercial and academic) in order to achieve two objectives:

(a) For the NGB Feedstocks and Process Technology

New solutions to enhance biofuels production efficiency, particularly the biotechnology knowledge acquisition is required. Shell has formed R&D collaborations with several biotechnology institutions. These collaborative projects are established between Shell and its cross-nation biotechnology institutions (both academic institutions and commercial-research organisations), in order to research and develop the NGB feedstocks and process technology.

Explained by van der Eijk: “Energy transition requires R&D efforts and technology investments to exceed the capabilities of individual companies (like Shell). We are seeing rapid developments in several fields of science relating to energy production. Biotechnology, will give rise to new biofuels production processes in delivering new materials and catalysts for cleaner processes. In the oil industry the dominant principle is “own technology first”, backed up by a strong patents position. The strength in technology at Shell is partly reflected by the large and growing number of patents we hold, more than 26,000. We can be proud of our technology track record. Our patents will remain very important in the future.” (Shell, 13 July 2007).

(b) To access biofuels R&D and production facilities

For the NGB development, more advanced research and production facilities are required. Since biofuels is a new business for Shell, in order to build these new infrastructure alone would involve high costs and high risks. Though partnerships, Shell can have the direct and immediate asses to its partners' existing R&D and production facilities, or at least to create the ability to share the building costs together in order to have these facilities established. These partnerships can help Shell to reduce the risk exposure on high investments, which can also help Shell to move into the NGB development and production in a shorter timescale.

6.4.3 Dealing with the Limitations of the Next Generation Biofuels to Meet an Increasing Demand

According to Broere (2008), the demand for biofuels is set to increase as the EU, the USA, and other countries gradually increase the requirements for the use of biofuels in transport. Through diversification of the NGB, each of the projects can contribute significantly in strengthening the capacity of the NGB. “We have been investing in many other potential biofuels solutions; cellulosic ethanol from straw, synthetic biodiesel from wood chips and petrol made directly from sugars. We increased our rate of spending on solutions like these,” said Routs (Shell, 29 October 2008). Since biomass is the most abundant biological material on earth, the potential of its production could be vast enough to support future demand. There are three types of biomass source under Shell's R&D: firstly the forest residues; secondly, the agriculture residues/agriculture by products (whole plants after fruits have been harvested, like wheat straw) and thirdly, the energy grasses.

From the Webchat (2009b), Mike Goosey-the Manager Biofuels R&D at Shell commented: “If biofuels are to help meet the predicted level of demand for transport fuels, we are going to need non-food feedstocks that can be grown without competing with food. Perennial grasses are one of the options that we are looking at because it is possible to convert the tough molecules that make up the cell walls of grasses such as switchgrass and miscanthus into bioethanol using advanced processes.”

For biodiesel, Shell is exploring the use of microalgae which can be grown in marine water and is capable of generating large amounts of oil per hectare. The most important concept here is that, there is no single generation that could claim to be large enough to support the entire world/national road transport fuels demand. Only the combination of these different generations of biofuels and the diversification of different the NGB feedstocks can gradually build up biofuels' capacity, in order to fulfil both the government mandates, as well as the increasing future demand.

6.4.4 Dealing with Risk and Uncertainty of Social Acceptance

Apart from using its corporate media (as discussed at 6.3.3.1), Shell is also collaborating with the world's major automobile manufacturers, in portraying their "halo" effect on its products. Ferrari and Ducati are two of the world most advanced automobile manufacturers in racing cars and racing motorbikes. These two companies are actively involved in three world recognised events: Formula One (F1), Moto Grant Prix (MotoGP) and Superbike Racing. These events are the highest class of automobile racing events which capture global attention in many aspects[192].

For many years, Shell is one of the key players for in these three motorsports. Shell has established strong relationships with a number of the automobile manufacturers, but has cemented the relationship with Ferrari and Ducati. Shell is the main fuel and lubricants supplier to the race contestants of Ferrari and Ducati. Besides, Shell has formed the technical partnerships with Ferrari (refer appendix 6.4.1) and Ducati (appendix 6.4.2) for a long-term race-fuel development.

(a) Testing BTL Diesel, 5% Blends with Shell V Power Diesel at the 24 Hours of Le Mans Race in France

Shell put the 5% Biomass to Liquids (BTL[193] through its collaboration with Choren), blend into Shell V-Power Diesel as the race fuel, for the 24 Hours of Le Mans race in France on 14 June 2008, and again on 11 June 2009 (as the second time BTL test).

192 the sophisticated automobile technologies applied, the cutting edge vehicles designed, the skilful racers, the challenges of the circuits, and the fuel technologies powering these racing automobile.
193 BTL is a synthetic diesel fuel made from non-food biomass, such as forest residues and waste wood/wood chips. A small amount of this new biodiesel has been blended into the Shell V-Power Diesel race fuel (together with the established GTL-gas to liquid component in the Shell V Power Diesel) (Shell, 28 May 2008).

The 24 Hours of Le Mans race provided a test bed for this product (Shell, 28 May 2008; 11 June 2009).

(b) Testing Cellulosic Bioethanol, 10% Blends with Shell V Power Gasoline at the 24 Hours of Le Mans Race in France

Shell demonstrated the blending of its 10% cellulosic ethanol, into its Shell V-Power fuel, at the 24 Hours of Le Mans race, in France on 13 June, 2009. This was the first time the 2G bioethanol was used in the gasoline at the 24 Hours of Le Mans race (Shell, 11 June 2009).

The 24 Hours of Le Mans race in France is one of the world’s sport car races which entirely challenges the endurance racing; testing not only the skills of the driver, the automobile technology, but also the fuel technology in supporting the 24 hour event. The event takes place annually in France, and runs on circuit comprising of a designed racing circuit and closed public roads. Since biofuels is a new business for Shell, and Le Mans is one of the world’s leading event, introducing the blends in this race allowed Shell to use this race event as a testing bed for its fuel products (twice testing for the 5% BTL diesel, and once testing the 10% 2G bioethanol), while at the same time promoting its biofuels to help gaining public confidence towards its products.

(c) Shell Blends Advanced Biofuels into the Scuderia Ferrari Race Fuel for 2010 Formula One (F1) Season

On 13 March 2010, Shell announced that the F1 fuel supplied for the Scuderia Ferrari[194] contained cellulosic ethanol made from wheat straw[195]. This was be the first time a 2G bioethanol has been used in the Shell V-Power race fuel used by Ferrari during the F1 Bahrian Grand Prix (Shell, 13 March 2010). On 19 October

194 It is the name of the racing team division of the Ferrari automobile company.
195 The cellulosic ethanol is produced at Iogen Energy’s demonstration plant in Ottawa, Canada, using wheat straw.

2010, Shell further announced that it blended biogasoline[196] to the Scuderia Ferrari race fuel at the South Korea F1 Grand Prix (Shell, 19 October 2010).

The partnership built among Shell, Ferrari and Ducati are sharing each others' "halo effects", surrounding the "high quality" of Shell fuel and lubricant products in supporting the "high performance" of Ferrari and Ducati, resulting in many world-recognised achievements. These messages and the big names presented, have gained wide public confidence and institutional trust, over the quality and performance of Shell's products. For many years, Shell has utilised the racing events and collaborations with the automobile manufacturers to have its fuel products regularly tested under the extreme conditions of high performance racing. The NGB testing performed over recent years, is designed to promote its NGB even though they are not yet commercially available.

6.4.5 Continuing the Next Generation Biofuels Development During the 2008 Economic Recession

The end of 2008 marked the beginning of the global financial crisis. Most of the companies opted for capital freezing, rather than the continuation of investments in the NGB R&D projects. The previous examples discussed by Elliott (2003) in his work, some of the RE projects were suspended due to the economic downturn, which caused by funding reductions. However, Shell is still proactively continuing its NGB R&D projects. Routs explained: "When times are tough as they are now, some companies may take a short-term view and cut back on research and development spending. At Shell we take the long-term view. We can maintain our significant investment in developing the next generation biofuels that we believe will be an essential part of the transport fuel mix. That is because the energy challenge will be with us a lot longer than turmoil in the financial markets" (Shell, 29 October 2008).

Sweeney commented, "The demand for energy will continue to surge. Today's period

196Biogasoline has been produced by Shell's technology partner Virent at its facility in Madison Wisconsin, USA.

of economic slowdown may moderate demand growth for a while, but the longer-term trend is still upwards. That is because 3 billion energy consumers will be added to the world’s population during the first half of this century. And those people would like access to personal transport. We think biofuels will be an essential part of the transport fuel mix, we have increased our investment in research and will be even more focused on biofuels in 2009 and 2010.” Talking about the near term demand which evidences the current biofuels consumption, Sweeney added **“**Europe, in particular, is a big consumer of biofuels, while in the US this is just starting to take place. We would expect growth leading to the long-term**”** (Webchat, 2009b).

The determination of Shell, to continue its NGB R&D projects despite the financial crisis hitting the global economy badly is evident. Firstly, an understanding of the expected exponential growth of future energy demand, Shell has to be ready within five-to-ten years (from now) to materialise the NGB. Secondly, since USD1.2billion has already been spent for the NGB R&D projects, it would create devastating losses if these projects have to be called off before their completion. The 2008 financial crisis was unexpected, caused by the banking industry. Yet, the existing invested R&D projects have to continue, with the clear objective of achieving the commercialisation of the NGB. Thirdly, the financial downturn is expected to create a lower/stable level of energy demand. Saving energy has been desirable, not only to counter concerns about climate change, but also to reduce household/industry expenditure. Therefore, this down-turn period is the time for the oil companies to embark on the intensive NGB R&D, sharing the expected/unexpected R&U with its partners, and to be ready for the rapid growth in energy demand after the economy recovers.

6.5 Conclusion

The regulators' mechanisms instituted to deliver biofuels deployment and development, have built up a strong confidence for Shell in executing its biofuels supply, as well as pursuing the NGB development. Backed by three political driving forces from the regulators (of different levels) for biofuels adoption, Shell's rationales to engange in the biofuels business are seamlessly matched with these driving forces, which are further supported by its economic motivations.

Shell has enganged in some aggressive moves to promote its biofuels business. Shell began the NGB R&D in 2002 which resulted in an early pilot market testing for one-month of its wheat straw bioethanol supply in Ottawa. Besides, Shell was innovative in utilising its organisational media to promote its biofuels products (particularly its NGB). It has used its coporate website, webcast speeches and webchat and social media sties (YouTube); all of which have been utilised to disseminate its corporate information. Shell participates in world-wide first class motor racing events and uses its partnership with race teams as a test bed for the NGB biofuels, as well as to promote its products, even before they are launched.

Operating within a regulated market, the biofuels market has continuous interventions from the regulators. Shell as one of the biofuels suppliers has to comply with the rules and regulations, in order to be allowed to supply biofuels and to sustain its biofuels business. The G&S criteria have been adopted as one of the criteria for Shell's biofuels deployment and the NGB development. The message that Shell wants a G&S biofuels is clearly projected through its corporate missions, as well as its corporate publications. Its participation in various roundtables, and its internal SSP play a significant role to ensure that Shell's suppliers are committed to the G&S biofuels supply, and helping Shell to comply with the RFA Meta/Qualifying standard and the “Carbon and Sustainability” reporting system.

Chapter 7: Discussion and Analysis

Preface

Recall the overarching research question "How the major actors-the Scottish Government (SG) and the oil companies interact with one and another to deal with risk and uncertainty (R&U) arising from technological change during a technology deployment and development?" This main research question is supported by five sub-questions, focusing on the SG and two of the oil companies (BP and Shell) respectively[197] with the ultimate aim of to achieve the five research objectives set[198]. To present the progress of biofuels deployment in the UK and to detail biofuels development; this chapter has been arranged in a way to demonstrate the flow and proliferation of these two issues. This is to ensure the clear separations between biofuels "deployment" and "development" stages, to answer the respective research sub-questions, and ultimately to achieve each of the research objectives.

There are five sections in this chapter. The first will focus on the actors (the SG and

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197 The sub-questions are divided into two categories of actors: The SG and oil companies
The SG:
(a) How biofuels became one of the current renewable energy sources for transport?
(b) What are the Scottish Government's roles in biofuels deployment and development?
(c) What mechanisms are in place to create a supportive environment for oil companies in pursuing biofuels deployment and development?
(d) What are the risks and uncertainties that appear during biofuels deployment and development?
(e) What strategies have been applied to counteract with the risks and uncertainties arising during biofuels deployment and development?
Oil Companies:
(i) What are the rationales that moved these oil companies into biofuels business?
(ii) What are the oil companies' role in biofuels deployment and development?
(iii) How the oil companies have been reacted to the government initiatives for biofuels deployment and development?
(iv) What are the risks and uncertainties appeared during biofuels deployment and development?
(v) What strategies have been adopted to counteract the risks and uncertainties arising during biofuels deployment and development?

198 Research Objectives
1. To investigate the driving forces for the government and the oil companies in taking biofuels as the current renewable energy source for transport.
2. To determine the respective roles and responsibilities of the government and the oil companies in biofuels deployment and development.
3. To understand the mechanism which delivers biofuels deployment and development, and the interactions that take place between the government and the oil companies
4. To identify the risks and uncertainties faced by the government and the oil companies during biofuels deployment and development.
5. To examine strategies adopted by the government and the oil companies to deal with risks and uncertainties arising during biofuels deployment and development.

the oil companies) who have been involved in biofuels deployment. It has to be stressed that, since the UK is a unitary state with a devolved system of government, the UK biofuels deployment is determined by the UK Government and influenced by the EU. Hence, biofuels adoption in Scotland is not a single cell operation of the SG[199]. The existence of the EU and the UK Governments influence signifies the multiple roles of the SG-not only as the regulator, but also as the executor of biofuels implementation in Scotland. Therefore, both the EU and the UK governments have determined/influenced the SG's actions, and shaped most of the UK/Scottish biofuels policies. This is important to ensure that, Scotland-as a part of the UK, is aligned with the national agenda and complies with the EU Single Market Principle under the European Economic Community. This answered the sub-question (b) the SG roles in biofuels deployment (shown at the footnote).

Since the EU, the UK Governments and the SG have all had an involvement in the biofuels adoption, the commencement of biofuels was driven by the respective objectives of different regulators at different levels. The research findings shown that, these objectives were not unique to the different regulator, but were in fact, some common driving forces shared amongst these regulators. This answered the sub-question (a) (shown at the footnote). Besides, the oil companies mainly acting as the 1G biofuels supplier, are also driven by the economic interests of biofuels businesses, which has also answered the sub-questions (i), and (ii) (shown at the footnote). Through mechanisms applied, strategies implemented and the interactions generated, these actors have deployed the 1G biofuels. This then answered sub-questions (c) and (iii) (shown at the footnote).

Hence, the first section has analysed the respective roles and responsibilities of the governments and the oil companies in biofuels deployment. This section has also investigated the driving forces for the governments and the oil companies in opting for biofuels, while explaining the mechanisms and strategies put in place which

199 Scotland has to comply with regulations and targets issued by a higher authority and cannot decide to issue their own guidelines (bind by the Reserved Matters) which fall short of international/national guidelines and targets.

deliver biofuels deployment. Since any new technology introduction into a new marketplace will face a certain degree of R&U; the EU, the UK Government, the SG and the oil companies, all have to ensure that the expected R&U were managed, in order to set a path for the ease of biofuels adoption. Several expected R&U during the technology deployment have been identified by Elliott (2003), Rosenbloom and Kantrow (1982), Pearson (1991) Rosenberg (1994) and SpecialChem (2011) report; subsequently made the identifications of R&U during biofuels deployment clearer.

Looking at the mechanisms applied and the strategies implemented, these methods are playing multiple roles. On one hand, they are set to facilitate biofuels introduction, while on the other, they are also the methods established to resolve the anticipated R&U which might hinder biofuels implementation. Therefore, in section two, the research answered the sub-questions (d), (e), (iv), (v), for both the governments and the oil companies. This section has identified the expected R&U faced by these actors during biofuels deployment, and examined the strategies adopted to deal with them.

The analysis from section one and two concluded that biofuels are shaped by different stakeholders' interests/objectives and various social forces. Biofuels adoption in the UK is tailored to suit the local requirements-which the UK adopts biofuels for the objective of reducing CO_2/GHG in the domestic road transport system. The defined roles between the regulators and the oil companies are set to ensure that each of their responsibilities are carried out, to ascertain an efficient operations under the biofuels regulated market (BRM). The mechanisms and strategies are devised, to control biofuels deployment and to achieve the respective interests/objectives of the stakeholders; and most importantly to resolve the anticipated R&U arising during biofuels adoption. These are then summarised and presented in Model 1.

The third section will explore two systemic risks that emerged from the 1G biofuels deployment. These systemic risks were unanticipated. Consequently, new actors emerged, demonstrating the institutional/power switch with the new demand for the enforcement of green and sustainable (G&S) biofuels criteria on the existing and the future biofuels products, production and supply. The governments and the oil companies took action through restrategisation and by strengthening the existing mechanisms, brought the systemic risks under controlled/managed. The discussions were furthered developed with the identification of confluence factors which caused the systemic risks to happen, and some empirical suggestions made to avoid the systemic risks from reoccur.

The fourth section will examine how the nine criteria/requirements for the next generation biofuels (NGB) were developed. These nine criteria/requirements were shaped by the various stakeholders [200] after the systemic risks occurred. Concentrating on the G&S criteria, the NGB has been largely shaped, not only to allow the pursuance of biofuels on political and socioeconomic benefits, but also to safeguard the socioenvironmental welfares. These are presented in Model 2.

Finally, at section five, we will focus completely on the issues of biofuels development. This section answered the remaining sub-questions of the SG and the oil companies in the NGB development. The section has investigated the respective roles and responsibilities of the SG and the oil companies in biofuels development; the mechanism put in place to deliver biofuels development and the R&U identified along with the strategies adopted to deal with them.

7.1 Governments and Oil Companies in Biofuels Deployment

Biofuels adoption is fostered by these two actors (with their respective interests) under the regulated market. These interests can be seen as a combination of both external and internal motivations. The external motivations include the social, economic and environmental gains from biofuels adoption. Whereas, the internal motivations reflect the self-referential aspects of political stability for the regulators,

200 The EU/UK and the Scottish governments, the oil companies, and the newly emerged actors like the international/national social movements/environmentalists and various biofuels roundtables.

and profit making for the oil corporations. Therefore, these two actors go together like bread and butter, collaborating along biofuels deployment; not only helping each other to achieve their objectives, but also protecting each other's interests.

According to Mallon (2006), the energy market might need to be reformed as some renewables will be integrated into physical/management systems which have not been designed for this type of distributed generation. However, this does not happen to biofuels businesses since they are accommodated in a dominant position that vertically integrated oil companies in the fuel supply.

The BRM is similar to the oil regulated market. It is, basically, one of the extended operations from the oil companies. The BRM is a market where there is a degree of supervision/intervention by the governments concerning permissible price movements and market behaviour for biofuels adoption. Meanwhile, the oil companies are responsible for a consistent biofuels supply[201]. Since biofuels and hydrocarbon are supplied through the oil companies-which seem to be a natural oligopolistic industry; therefore, biofuels have been concentrated in the hands of a few major firms, which have sought to influence the markets they operate. The existence and the apparent inevitability of oligopoly structure that lack of competitive pressure have proved a motive for a government’s intervention. The governments have to create a balance in protecting the economic interest of the oil companies, as well as to safeguard the public socioeconomic welfare.

In the UK BRM, most policy making decisions are made at the highest level of the regional political authority-by the EU. This policy is then passed down to the member states of the respective national level like the UK Government. In reality, the EU is formed by the representatives from each of the member states. Therefore, most of the decisions made are nearly unanimous. Biofuels uptake was due to the EU/UK Governments' mandate. Through regional and national policies formulation, biofuels

201 Biofuels have to be distributed which are convenient for accessibility, constant for availability and quantity, and consistent in quality. Under the RTFO, all oil companies are obliged to comply with the measurements, and to achieve the annually-increasing-targets of biofuels blend in petrol/diesel.

were implemented in the UK. This top-down pattern of political power reflects the institutional structure of the EU/UK, operating under the Single Market principle within the BRM.

At the national level, the UK Government acts as the national principal-with executive legislative power, links with the devolved governments like the SG, and passes down regulatory decisions made[202] to the agents (the oil companies as the biofuels suppliers). The UK Government is responsible for the national policy executions, must ensure the SG is adopting the national biofuels policy. Besides, the UK Government also monitors the oil companies' performance to ensure their biofuels supply comply with the state law-the Renewable Transport Fuels Obligation (RTFO).

An agency created by the Department for Transport (DfT)-the Renewable Fuel Agency (RFA), is an agent of the DfT. The RFA is empowered by the DfT, to monitor biofuels deployment in the UK, through the monthly biofuels “Carbon and Sustainability” [203] reporting system from data fed back by the oil companies. Therefore, what is signified from this “principal-agent” relationship-as advocated by Gregory and Stuart (2004) is that, there are many overlapping roles taking place. One principal could also acting as an agent for another principal [204]. Thus, these identifications are merely to present the relationships, interactions and the responsibilities exist between the decision maker (principal) and the decision executor (agent).

When interests generate motivations, they subsequently drive up the momentum and commitments to achieve the goals. Meanwhile rules (discussed in appendix 2.1.2) lay out the clear roles and responsibilities, which have been assigned to the governments

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202 Information appears in the form of policies, directives, acts, regulations, standards and mandatory targets.

203 quantity sold on particular month, the source of the biofuels and the CO_2 savings achieved.

204 The UK Government acts as an agent for the EU, while it is also the principal in the UK. The RFA acts as the agent for the DfT, while simultaneously it is playing a role as the principal for the oil companies.

and the oil companies with regard to their respective operations/functionality. These roles and responsibilities, not only can facilitate efficient decision-making, to ensure an effective biofuels execution, but also can determine the appropriate action to be taken when problems/R&U arise during biofuels deployment.

7.1.1 Governments' and Oil Companies' Motivations for Biofuels Deployment

There was an increasing interest from the EU/UK Governments in adopting biofuels, as a response to concerns on oil dependence associated with energy security and greenhouse gases (GHGs) reductions. McNeely-the Chief Scientist of the International Union for Conservation of Nature summarised: “With soaring oil prices, and debates raging on how to reduce carbon emissions to slow climate change, many are looking to biofuels as a renewable and clean source of energy” (BBC News, 22 September 2006).

There were three political backdrops to drive a regional/national biofuels adoption. Firstly, there was regional and national pressure to reduce GHGs in road transport as quickly as possible. This is because the GHGs emission is a daily problem. It is important to have the emissions cut as early as possible, in order to abide by the obligatory requirements of the EU Biofuels Directive (EUBD) 2003 and Kyoto Protocol 1997; and to avoid from being penalised by the regional/international community if any country fails to achieve such compliance. Secondly, it was in both the regional and national interests to achieve “partial” energy security and to lighten the high dependency on the imported oil from any politically unstable region.

Accepting the fact, the exponential growing demands on energy for the transport system could be seen in the next decade. Consequently, oil and gas will struggle to meet up these future needs. Thirdly, to prosper the regional/national economies by gradually switching from the centuries old of oil-dominated-economy towards a green economy-that emphasises on renewable energy (RE) generations, carbon management and ecological conservation. Recent evidence shows that, most of the agricultural industries in developed/developing countries were profited from biofuels feedstock growing. Due to the growing demand and the increase of biofuels international trade, this has generated more job opportunities and wealth creation for the agro-economy.

Meanwhile, oil companies like BP and Shell are responding to the governments' vision of green economy, the mission of energy security, and the objective of GHG/CO_2 reduction in road transport through their participation in biofuels supply. Apart from the fulfilment of the regulators' policies and agendas, the main motivation for the oil companies in the biofuels business lies in the economic benefits of profit making.

There are also three corporate driving forces, which led BP and Shell to enter the biofuels businesses. Both BP and Shell have been discussed separately in Chapter 5 and 6, are summarised in Table 7.1.1. From this presentation, we found that, most of them could be correlated, to explain the commonality in shaping both companies' interests in biofuels, as well as the alignment with the governments' motivations.

Table 7.1.1: Summary of Three Corporate Driving Forces on Biofuels

BP	Shell	Common Attributes
Towards energy security	Energy challenge	Both are related, due to the increasing road transport energy demands, rapid industrialisation, the depleting oil and gas reserves, and insecure sourcing from political unstable regions.
Environmental, concern in combating climate change	Biofuels for CO_2 reduction	Both are related, as the characteristic of biofuels in GHG/CO_2 reduction from tail pipes, and provide carbon neutrality.
Prospering agricultural industry	Government policies and targets	They are not related, yet could justify the different directions for BP and Shell. To comply with the government's targets, Shell is embarking on the NGB development; while the rational of prospering agricultural industry led BP to invest in large-scale jatropha and sugarcane plantations.

Source: Summarised by the researcher

7.1.2 Matching the Governments' and the Oil Companies' Motivations

To make sure a biofuels implementation could be successfully executed, both the regulators' and the oil companies' motivations have to be aligned, so that their collaborations could be coordinated within a regulated market. The research found a seamless match between these stakeholders that subsequently generated the momentum for commitments to the regional/national biofuels deployment.

(a) Towards energy security

Energy security is important for the EU and its member states. Oil and gas are commodities which are interwoven with political, social and economic stability. If any disruption caused a shortage, this could render in a dramatic increase in prices. This is because, apart from powering the transport system, oil and gas are heavily used for daily activities in manufacturing, commercial operations and household living[205].

Historically, the oil price fluctuations from previous years[206] harmed the global economy. Furthermore, oil dependency from the politically unstable nations like the Middle East, Persian Gulf and Nigeria; puts the oil companies' operations in a vulnerable position. Accepting that demand for oil and gas will grow exponentially over the coming years/decades whilst oil and gas reserves are rapidly depleting resources; energy prices are getting more expensive. Thence, energy security has become one of the utmost political, social and economic concerns. Biofuels, which are derived from biomass, can be grown through agricultural power or at non-oil

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205 oil and gas are the main energy source in powering machineries for manufacturing, keeping the transport system running to foster trade, increase mobility and generating heat/electricity for households. Besides, the petrochemical industry which uses oil as a raw material would be largely affected when oil supply is insufficient or is too expensive.

206 Oil crisis:

(a) 1973 oil crisis as OPEC oil export embargo by many of the Arab oil producing states, in response to western support of Israel during the Yom Kippur War.

(b) 1979 Iranian revolution.

(c) 1990 spike in the oil price due to Gulf War.

(d) 2000 inflation due to a world peak in oil demand.

(e) 11 September 2001 attack in the US.

(f) 2003, invasion of Iraq

(g) forecasted 2014 peak oil crisis (Campbell, 2005).

producing nations; could insure a "partial"[207] energy security or provide a small-scale of oil substitution[208].

(b) Using Biofuels for the Road Transport GHG/CO_2 Reduction

The threat of climate change has spurred a great interest in finding new energy sources that do not add to the amount of GHG/CO_2 currently in the air. Regulated by the EU, many policies are capping today's GHG/CO_2 emissions from various sectors[209]. Since the world needs to double its energy supplies, while at the same time cutting emissions in half, BP and Shell have to diversify their energy profiles to take in the lower emission sources like biofuels. Biofuels could reduce 2.5%-4%[210] of CO_2 emission from vehicle tailpipes. Besides, the carbon neutrality is significantly helpful, if the activities along the value chain of biofuels operation could be managed properly to take in the G&S principles.

(c) Prospering Agricultural Industry

Many governments in the developed/developing nations want to see their agricultural communities become more prosperous. Biofuels feedstock farming is not only benefiting developed nations such as the US[211], Canada, France and Germany; but also the developing countries like Indonesia, Malaysia and Brazil which agricultural is their national economic pillar. Currently, there are three cross-border large-scale plantations (two jatropha projects and one sugarcane project) launched by BP, which signify BP's interest towards the agricultural sector.

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207 This is because, the capacity of oil and gas are far too far reaching. They have penetrated into many industries and dominated the world for more than a century. They are powerful in mechanising the global economy and fostering the social interactions. With this large capacity and dominant role, they could never be replaced by a single source of biofuels alone.

208 by using flex-fuel/biofuels cars. However this is still remains a small-scale application due to: the expensive of a hybrid car, the low accessibility of the neat biofuels supply and the inadequacy of technical/maintenance support for such green cars.

209 transport, energy generation, industrial, commercial and households energy consumptions.

210 5% biofuels blend would result in a carbon reduction of around 2.5% (biodiesel) and 4% (bioethanol) (Whatagreencar, 2008).

211 In 2006, biofuels added USD41billion to gross output, and created 160,231 jobs in all sectors of the economy. In addition to providing a growing and reliable domestic market for American farmers, the biofuels industry also provides the opportunity for farmers to enjoy some of the value added to their commodity. Farmer owned ethanol plants account for 43% of the US fuel ethanol plants and almost 34% of industrial capacity (Dinneen, 2007).

(d) Responding to the Governments Biofuels Policy

Shell foresees the increasing targets from the EUBD (2003), the RTFO (2008) and the EU Renewable Energy Directive-EURED (2009). Although these targets are low in the early years, when 5% is required in 2013/14 (by the RTFO) and 10% alternative fuels in 2020 (by the EURED), these targets will pressure Shell into producing a consistent of biofuels supply. To support these regional/national targets, all of the NGB R&D projects conducted by Shell are aim to ensure a reliable and greater volumes of biofuels can be produced.

7.1.3 Shift of the Hydrocarbon Paradigm towards Biofuels Deployment

We observed the policy framework and the regulatory instruments established, many of them demonstrated some of the key features[212] of a successful RE policy advocated by Mallon (2006). This explained the rapid shift of the hydrocarbon paradigm towards biofuels implementation has been progressing well, according to what has been designed/planned.

Biofuels deployment is operating under a regulated market. Both the regulators and the oil companies are committed to ensure the ease of the technology adoption. The regulators initiated biofuels introduction through policy formulation. These policies were transparent-as described by Mallon (2006) to minimise the R&U as much as possible. The political messages/objectives were delivered through policies[213] which brought together both the regional and national governments' visions/mission/objectives, while being supported by measurable social, economic and environmental benefits. Since biofuels adoption in the UK/Scotland was not the decision of the UK/SG alone, instead, it was the result of the political decisions initiated by the EU which then delegated to the member states including the UK. Therefore, the interwoven political agendas of regional and national governments

212 [1]energy market reform, [2]high transparency, [3]stable, [4]well-defined objectives, [5]appropriately applied incentives, [6]well-defined technology and [7]well-established contextual framework.

213 The UK Powering Future Vehicles Strategy (2001), the EU Biofuels Directive-EUBD (2003), the EC Biomass Action Plan (2005), the UK RTFO (2008), the EU Fuel Quality Directive-EUFQD (2009), the EU Renewable Energy Directive-EURED (2009), Scotland's Consultation on Low Carbon Vehicles (2009) and Scotland's Renewable Action Plan (2009).

were found in the UK/Scottish biofuels policies. This policy structure provided a stable/strong foundation-as depicted by Mallon (2006) for biofuels introduction since the national biofuels policy of the member states is backed by the regional regulators.

The EUBD (2003) was first formulated which required a target of 5.75% blend of biofuels (on the basis of energy content[214]) on all member states' transport fuels by 2010. This was then increased to a mandatory 10% of alternative fuels by 2020 under the EURED (2009). These political targets have then been transposed/incorporated into the UK RTFO. In order to achieve these regional targets, the UK RTFO has broken down these regional targets and laid out step-by-step annually-increasing-national-targets. The RTFO was commenced on 15 April 2008, requires the suppliers of hydrocarbon to ensure that a specified percentage of the road fuels they supply in the UK is made up of biofuels. The target began at 2.5% in 2008/2009, and rises to 5% in 2013/2014. We would expect the targets from the RTFO would be increased until year 2020, in order to align with the EURED (2009) mandatory 10% target by 2020. Therefore, the EU/UK and the SG are setting ambitious targets to help biofuels claim a larger share of the regional/national road transport fuels.

Compared with other EU member states, the UK adopts biofuels to reduce GHG/CO_2 for its national road transport. This well defined objective-explained by Mallon (2006), has appeared across all the UK/SG policies, ranging from combating climate change, RE generation to building a low-carbon transport system. Furthermore, the environmental concern has been prioritised as the central focus of many policies formulation.

To achieve the objective of biofuels adoption, regulatory instruments have been facilitated/applied. These included rules and regulations, standards on biofuels quality[215], mandatory annual targets (RTFO), the Renewable Transport Fuel (RTF)

214 The correlation is 5% by volume which equals 4% by energy (Gallagher, 2008)
215 Biofuels used in the UK, have to comply with the European Standards biodiesel EN 14214 (2003) and the bioethanol EN15376. This is important for quality control and standard unification which helps to foster international trade and regional/local market adoptions.

Certificate-which acted like a business licences enforced by the RFA[216]; and the vehicle manufacturers'[217] standard warranty remains intact voluntarily, when biofuels are incorporated into mineral fuel at a rate of 5% by volume. Besides, financial incentives (20p/litre[218]) are appropriately applied-as depicted by Mallon (2006), where the incentives were accessible and open to all biofuels commercial players who are supplying biofuels blends in the UK. Overall, the contextual framework-described by Mallon (2006) for biofuels introduction was well-established. The policy makers and the oil companies are operating within the regulated market. The higher levels of cooperation and dissemination exist, the more effective the biofuels deployment was to be.

7.1.4 The Existing Social Requirements and the Technical Constraints that Favoured Biofuels Adoption

Finding alternatives for power generation is comparatively easier than finding alternatives for energy used by the road transport system. This is because, the upstream power sources could be changed by switching from coal/oil plants to appropriate RE; while the transmitting/distribution infrastructure downstream could be remained/unchanged and continue to support manufacturing, commercial and household activities.

The alternatives for transport fuels are far more complicated, due to the technologies being entrenched by current social requirements and automobile technological constraints. This could be explained from the perspectives of the existing

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216 The RFA is established by the DfT to manage, control and monitor biofuels supply in the UK. Both Meta and Qualifying Standards of the RFA are emphasis on the G&S of biofuels on the products, the production and the supply process. All the oil companies operating in the UK have to report their monthly “Carbon and Sustainability” data to the RFA. The data consists of quantity sold on particular month, the source of the biofuels and the CO_2 saved. This complies with the interactive approach advocated by Hood et al. (2004b), with the regulator imposing periodic reporting requirement on the oil companies to come forward with information, and then responding to the content of the information/data reported.

217 Represented by ACEA-European Automobile Manufacturers' Association, JAMA-Japanese Automobile Manufacturers Association and KAMA-Korean Automobile Manufacturers Association.

218 Biodiesel and bioethanol are taxed at 20p/litre less than petrol and diesel. This support is guaranteed until March 2010. The biodiesel incentive has been in place since July 2002, while the bioethanol was since January 2005 (DfT, 2008). The aim for this incentive is to keep the production cost and sourcing cost low, to ensure affordable prices can be passed on to the consumers. The tax concession is likely to be phased out in favour of the buy out after March 2010.

infrastructure which associates with high switching costs; and green automobiles that link with the manufacturers' capabilities and market responses.

Firstly, the existing supply infrastructure is set for hydrocarbon. It consists of well-connected pipelines, storage-tanks, oil trucks and gas stations which have been in operations for decades. Besides, the existing automobiles are powered by internal combustion engines (ICEs). These supply/distribution infrastructure and the ICEs are designed to handle "liquid fuels" only. Thus, the earlier technological choices have patterned the subsequent development (Rosenberg, 1994). Consequently, the oil companies were forced to look for alternative liquid fuels that are compatible with hydrocarbon. This is aimed to prolong the use of the existing infrastructure and ICEs. Besides, this could also avoid the high switching costs (from corporate and personal investment[219] on new technologies) and allows for immediate applicability/use.

Secondly, while the alternative engine technologies[220] seem to be catching up, the world's billions of ICEs that fuelled by hydrocarbon are expected to remain for another thirty-to-fifty years. In order to produce a hybrid car, this would have to rely much on the technological know-how of the automobile manufacturer, combined with a positive social climate[221]. To date, the world's most advanced green car manufacturing nations are mainly concentrated in the US, Japan and the EU. However, there are still many automobile manufacturers who do not have an adequate institutional knowledge/capability to manufacture these green cars[222.] This is further hindered by the 2008 financial crisis, the current high cost of the green cars, the low accessibility of the alternative fuels and the inadequacy of the technical support for green car maintenance/service. Thirdly, even though the public has the

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219 switching ICE to a green car, constantly servicing the green car to maintain its performance
220 flex-fuel, H_2 , electric/fuel cell, neat biofuels and potentially solar cars.
221 such as a clear political direction, the government fiscal support, social response on new technology adoption and various institutional involvement.
222 There are fifty world automobile manufacturers (data based on the Organisation Internationale des Constructeurs d' Automobiles, 2008). Fourteen* manufacturers are embarking on R&D, and only four (Toyota, Honda, Ford and G-Wiz) have successfully marketed their products.
*-Hybrid cars from Honda, GM, Ford, Toyota, Audi, Daimler and Nissan.
*-H_2 cars from GM, Ford, Honda, Fiat, BMW and Mazda.
*-Electric/Fuel Cell cars from Daimler, Fiat, Ford, Hyundai, Mazda, Peugeot, Volkswagen and G-Wiz.

environmental awareness and the collective social responsibility in cutting GHG/CO_2 emissions from road transport; in reality, the market response is highly sensitive to the cost-benefit logic. Therefore, oil companies have to be efficient in supplying RE which can be done in a more cost effective way.

Combined with social requirements and technological constraints of the alternatives transport fuels, biofuels provide some technical convenient as the effective solutions. Biofuels have been implemented in Brazil for more than three decades, while BP and Shell have been supplying biofuels in the US and Brazil for many years. The durations for biofuels implementation are credible in social, technical, economic and practical terms. Additionally, biofuels require low switching cost, since they are compatible with the current hydrocarbon distribution infrastructure and the ICEs; that allow them for an immediate execution. Furthermore, they could reduce 2.5%-4% of CO_2 from vehicle tailpipe. Hence these encouraging factors along with the technical convenience of biofuels (refer appendix 7.1.2) affirmed biofuels are well defined-as explained by Mallon (2006), and then selected as the front runner for the contemporary renewable energy for transport (REfT).

7.2 Social Construction of Risk and Uncertainty on Biofuels Deployment

Technology deployment is proceeds by the interaction of various social and technical elements. Therefore, technology, once implemented, not only reacts back upon its environment, but it also generates new implications (Clark and Staunton, 1989; Fleck, 1993). This section borrows the theory of R&U on technology implementation as advocated by Rosenberg (1994) and the SpecialChem (2011) report (discussed in 2.4.1) [223] , to analyse biofuels adoption and the social implications, which subsequently rendered to counterbalance the expected R&U-on technology applications, business operations and market acceptance (summarised in Table 2.4.2).

[223] Rosenberg (1994) analysis from (i) to (vi), SpecialChem (2011) analysis from (vii) to (viii)

(i) Ex ante uncertainty about biofuels use

Biofuels, which have been implemented in Brazil and the US for many years, would still appear in a primitive condition when operating within the EU/UK markets. This is because under the concept of “localisation”, new stakeholders are involved to establish a new set of regulatory and control mechanisms for regional/national biofuels deployment. Therefore, biofuels adoption in the UK needs the reconfiguration and localisation, in order to operate under these new contextual setting, and to comply with the regulatory requirements. This fits to Rip’s (1995) comments that introducing a new technology is not a straightforward matter, as there is no guaranteed recipe based on previous experience-even though both BP and Shell have years of experiences in Brazilian and American biofuels implementation.

(ii) The need for infrastructure

Certainly, biofuels are the new technology to the UK. They have the power of game changing, could switch the hydrocarbon-dominated-transport landscape towards low-carbon renewable fuels use. Yet, the technical conveniences of biofuels provided (discussed in section 7.1.4) do not require biofuels for an entire new system to be established to support their operations-as concerned by the SpecialChem (2011) report. Their compatibility with the existing hydrocarbon supplying infrastructure and the ICEs, allow their adoption with immediate effect.

(iii) Innovation causing competition between the new and the old technology

Generally, any technology (new or old) (particularly the consumer technology) will face a series of competition in order to gain a bigger market share. The theory of substitution advocated by Smith (1996) highlights the process by which a new technology would threaten the traditional technology, or vice versa.

Biofuels, since they are supplied by the same oil companies, they will not threaten the oil companies' conventional hydrocarbon business under the same economic objective. Furthermore, the oligopolistic structure of the oil market is naturally lacking of competitive pressure. Hence, this has eased the stiff competition between biofuels and hydrocarbon (stiff competition as concerned by the SpecialChem 2011 report) in serving the regional/national transport system. From the economic and technology perspectives, biofuels do not create a distinctive/entirely new and threatening technology. For the mid-to-long-term, they can provide the continuation of liquid fuel, either blended with petrol/diesel, or can be used in a neat form on specially-designed green cars. Besides, biofuels are one of the renewables, not only can sustain the oil companies' energy businesses, but also build up an alternative route, and gradually switch hydrocarbon to low-carbon energy supplies. Since oil and gas are depleting resources, most of the oil companies have begun venturing into RE business since year 2000. The political climate and social awareness are in place, to push the green economic evolution on RE generations.

“America is addicted to oil” said President Bush (2006) when he delivered his State of the Union address. Yet in reality, is not only America, but the whole world is dependent/addicted to oil. The discovery of oil in 1900 has almost penetrated into every aspect of mankind activities, and subsequently dominated many industries for more than a century. Because of the consequences of climate change, the world community awares of the peak oil issues. Biofuels as one of the renewables is complementing the road transport energy mix, at least to alleviate the pressures of low-carbon energy use, while also capable of meeting the increasing demands.

(iv) A new technology has the unanticipated applications

According to Rosenberg (1994), one reason why it has been difficult to foresee the uses of a new technology, is that, many inventions had their origins in the attempt to solve a very specific defined problem, yet turns out to have significant applications in totally unanticipated contexts[224].

224 One example being studied is the laser technology. Laser, which its eventual use in an industry has turned upon an extended improvement process that vastly expands its practical usages for other industrial applications. Laser was started from an industrial use for precision measurement, navigation and chemical research. It then expanded to different industries such as music for CD/DVD production, surgical procedure, printing industry and others.

However, biofuels are different as they are a social utility-a large-scale technology. The laser technological diversification was mainly driven by the cost-benefit logic, market demand and the decision made among the industrial players. Biofuels however, are operating under the regulated market control, with the continuous interventions from regulators, while the technology is supplied by the oil companies. Thus, what makes biofuels different from other consumer technology: apart from the "scale" of the technology, the dissemination would largely depend on these two significant decision makers (the regulators and the technology suppliers). Biofuels, at the current-to-mid-term implementation stage should not create any unanticipated applications, apart from their potential expansions to fuel other modes of transport like aviation or shipping[225]. If this could be applied, then we would foresee a more efficient use of low-carbon energy to power a bigger transport landscape.

(v) A new technology creates multiple impacts on other industries

Innovations often arise as solutions to highly specific problems. In some cases, a new technological capability may have multiple points of impact on another industry. What Rosenberg (1994) worries are the impacts of one technology innovation might create negative a chain effect spreading to other industries. Conversely, the 1G biofuels execution provided a profitable opportunity for agricultural based nations (refer appendix 7.1.4), and the related stakeholders (biofuels farmers, producers, suppliers and traders). This has created a new trend in fuel production-from a century of oil extraction that is completely based on the location of oil reserves, to biofuels production based on the geographical agricultural activities.

Besides, the NGB R&D projects have also benefited economically some of the biotechnology (academic and commercial) institutions. These projects are

225 Aviation and international shipping:
-The Virgin Atlantic Jet flight took place between Heathrow and Amsterdam used biofuels (mixture of Babasu nuts and coconuts). This has opened an opportunity for biofuels adoption in airline (BBC News, 24 February 2008).
-Besides, maritime transport has also opened another opportunity for biofuels use in sea cargos and ships. According to DfT (2007), the government is promoting biofuels use for international shipping.
-In 2010, the DfT conducted one of the projects, to develop analysis on scope for biofuels to play a part in delivering 2050 aviation CO_2 strategy (DfT, 2010a).

magnetising the oil companies, biotechnology institutions and agricultural industry for profit seeking and to achieve their respective economic objectives. Inevitably, the inter-industry flow took place for wealth creation among the stakeholders along the 1G biofuels deployment and the NGB development.

(vi) The identification of needs

Rosenberg (1994) advocates, the implications of new technology are not just a matter of technical feasibility or improved technical performance. They are rather the matters of identifying certain categories of human needs and catering to them in a novel way. This is because a new technology needs to pass a socioeconomic test, not just a technological one. What shapes it depends on the ability to visualise how it might be employed in a new context.

Since the introduction of the regional/national biofuels programme was initiated by political mandates, biofuels do not have the problems of gaining markets like conventional consumer technology does. This might give some advantages to the oil companies, since the entire region/nation could backup their sales. However, because of the massive scale of such technology and the huge markets that need to be satisfied, this technology would also generate R&U from the technological change, as well as during the deployment process. As such, most of the utilities like biofuels have to be placed under the context of a regulated market, with the involvement of government and the oil companies, to ensure the execution would be on track.

The main function of a regulated market aims to create a balance-so that, while concentrating on the economic progression of biofuels (profit seeking, national wealth creation, and technology development for both regulators and the oil companies), the socioenvironmental obligations are not be overlooked. Nowadays, the British public has a strong environmental awareness of climate change and they are concerning on the social responsibility in minimising the impacts of the carbon foot-print. Thus, biofuels use in their automobile could at least alleviate the carbon pollution, by reducing the carbon emitted from their vehicles.

(vi) The economy climate

Macro-economic risk such as the financial crisis since 2008 has delayed most of the technology introduction projects in the UK. Initially, we would expect the passive economic climate will jeopardise the biofuels introduction programme (the RTFO). Yet, todate, biofuels are still progressing under the RTFO.

Biofuels application under the RTFO has a set of gradually-increasing-annual-targets for the biofuels blend with petrol/diesel use in the UK. Meanwhile the RTFO is also looking forward at the innovations of the NGB development that emphasises on the G&S biofuels, which are expected would be materialised five-to-ten years from 2008. Consequently, all of these have generated two positive implications: Firstly, the targets have determined/guided the pace of the technological diffusion, which are entirely based on the regulators' mandates. Secondly, the achievement of biofuels adoption has been the first step in stimulating the economic transformation-from a hydrocarbon-dominated-economy, towards a green economy (refer appendix 7.1.5). What was worried by SpecialChem (2011) on insufficient resources allocation for the technology launch and the refusal of oil companies to commit in biofuels introduction/innovation did not happen. Although the oil companies have to deal with various costs[226] in biofuels operations, the policy laid out has driven up the confidence of oil companies to participate/committed in biofuels businesses despite the huge investment involved.

The regulators and the oil companies have a long-term view on biofuels progression since the RTFO does not have a cut-off date within the lifetime of its implementation. Therefore, oil companies were confidence on the political framework established-which is positively supporting biofuels for their long-term use/availability within the regional/national transport system. The financial resources were effectively managed/allocated. The UK Government is willing to provide the incentives and keep funding some local NGBs development projects, while the oil companies are using their private funds for the private NGB R&D projects. All of

226 include the managerial costs, the hardware costs, the R&D costs, the exchange rates and so forth.

these have minimised the R&U of biofuels deployment and development, enable the oil companies to pursue biofuels introduction/innovation with higher confidence, regardless of the current world financial crisis occurred since 2008.

(vii) Market acceptance of a new technology

According to SpecialChem (2011), there are some of the characteristics which customers want to avoid as much as possible the R&U arising during a technology adoption. Each of them are explained and analysed as below:

(a) Reliability: Biofuels have been adopted in Brazil for more than three decades which strongly demonstrates their reliability. Besides, the automobile manufacturers have provided a standard warranty for biofuels incorporated into mineral fuels at a rate of 5% by volume. This has strengthened the market confidence on biofuels use.

(b) Scalability and future availability: Biofuels blends will follow the annually-increasing-targets laid by the RTFO. The target will be increased till year 2020, to align with the EURED (2009) mandatory 10% target by 2020. Hence, biofuels introduction is for long-term.

(c) Standards: Biofuels have to comply with the European standards: EN14214 (bioethanol) and EN15376 (biodiesel).

(d) Cost: Biofuels are subsidised with tax incentives of 20p/litre. This help to ensure an affordable price for the market. No engine modification is required (switching cost) to adopt biofuels in the existing ICEs.

These benefits of biofuels technology were promoted. Baron (2011) suggests, mass education through media is one of the effective ways to reach the large population of the customer. Thus, the EU/UK Government and the SG, together with the oil companies are promoting the technical conveniences of biofuels through various media (print, electronic and internet)

In summary, the analysis of the social construction of uncertainty on biofuels deployment using Rosenberg (1994) and SpecialChem (2011) frameworks, could lead to the conclusion: that biofuels adoption in the UK, until this stage the R&U

were expected and manageable on the technology applications, business operations and market acceptance. The analysis which was also built on Social Shaping Technology (SST) angle, took into the consideration a range of social factors, including institutional, social, political, environmental and economic, which have patterned the biofuels implementation, influenced the content of the technology and their social implications (Williams and Edge, 1996).

7.2.1 The Expected Risk and Uncertainty Faced by the Governments and the Oil Companies during Biofuels Deployment

Since the expected R&U can have a multitude dimensions, the divisions of R&U which were faced by the regulators and the oil companies respectively, could separate the overlapping of the R&U, and contextualise them accordingly from each of their different perspective. The mechanisms and strategies applied, not only helped to foster the 1G biofuels adoption (discussed at 7.1.3), but they were also characterised by the risk preventive objectives, to have the expected R&U mitigated/resolved in order to ease the biofuels deployment.

Elliott (2003e) advocates a set of expected R&U from the regulators'[227] on RE deployment, with the counteracting strategies applied to mitigate them (as summarised in table 2.3.1 and 2.3.2). Besides, there are three[228] expected R&U from the corporate perspectives on technology adoption-advocated by Rosenbloom and Kantrow (1982), Pearson (1991) Rosenberg (1994) and the report from SpecialChem (2011) with the counteracting strategies to mitigate them (as summarised in table 2.4.2). This research utilised both of these frameworks for biofuels deployment analysis (summarised the findings in Table 7.2.1 and 7.2.2).

227 [1]Political support, [2]funding, [3]social acceptance, [4]technology, [5]institutional interests and involvements
228 [1]Technology, [2]business operations, [3]social acceptance

Table 7.2.1: Risk and Uncertainty and Strategies Applied by Regulators during the 1G Biofuels Deployment

Types of R&U	Findings	Strategies adopted
Political support 1. Lack of follow through when the project is under deployment.	1. Adequate of follow through during biofuels deployment.	1. Compared with the previous RE projects which mostly failed in the UK, biofuels deployment gained clear political direction from the EU who has formulated the EUBD (2003) and the EURED (2009). These were then further obliged to its member states-including the UK, to deploy biofuels for the nationwide road transport system. The UK RFA is established to execute the RTFO (2008), and to monitor the G&S biofuels supply in the domestic market. The SG involvement for biofuels implementation is obligated under the UK Reserved Matters. Therefore, biofuels adoption is collectively executed amongst the member states under the regional Single Market Principle and to achieve the Kyoto Protocol ratification. The deployment process is guided by the targets, unified standards, and backed by the regional political decision. Any R&U and issues faced at the member states level could be brought to the EU for further discussion. Hence, biofuels deployment is stronger than the previous failed RE projects-which entirely depend on the UK Government whom faced all the R&U alone.
Funding 1. Inadequate/discontinued financial support. 2. Require vast investments of time, capital and resources for technology deployment. 3. High capital/operation costs, with slow payback time. 4. High switching cost associates with new infrastructure construction.	1. Adequate financial support on biofuels with tax incentives. 2. Guided by biofuels targets set a bottom-up approach for biofuels deployment strategy, which does not require a large up front investments. 3. Low capital cost/operation cost, quick payback time. 4. Low switching cost as no new infrastructure is required.	1. Biofuels are taxed at 20p/litre less than petrol and diesel. 2. The EU/UK biofuels targets have set proper guidelines for increasing regional/national biofuels adoption. These targets-starting from a low percentage and increasing, allow the supply infrastructure and capacity to be built/upgraded gradually, in order to ensure these targets could be achieved. 3&4. Biofuels provide the most economic solution, due to the low switching cost involved, since there is no requirement for a new supply infrastructure establishment. The compatibility of biofuels with existing hydrocarbon supply infrastructure, not only secured low operation cost, but also allowed them to be adopted at the existing infrastructure/ICEs, with an immediate effect.

Social acceptance 1. Difficult establishment of new RE technology in marketplace.	1. Biofuels are not new technologies.	1. Biofuels have been implemented in the US for nearly five years and in Brazil for more than three decades. Therefore, these technologies are not new and have been proven on their practicality and executability.
2. Low market acceptance on RE technology.	2. Increasing global market acceptance of biofuels.	2. Many of the OECD countries showed their support on biofuels deployment. This has attracted other nations, to work on biofuels adoption. In the UK, due to the incentives, quality control and warranties provided by automobile manufacturers, all of these have encouraged the public acceptance on biofuels use.
3. Economic benefits and environmental impacts.	3. The UK is balancing economic benefits and environmental impacts.	3. The UK adoption of biofuels, is aimed at reducing the road transport CO_2/GHG. Hence, the RFA is established to monitor the G&S criteria of biofuels supplied by the oil companies.
4. Disinformation which caused low acceptance on RE technology	4. Accurate information from reliable organisational media, websites and reports.	4. The positive economic and environmental impacts of biofuels are promoted through corporate/government organisational media. These sources of information are convincing/highly reliable. The emphasised in safeguarding socioenvironmental responsibilities has appeared across most of the regional/national transport/biofuels policies, and corporate reports. Most of the information published is supported by consultants appointed and scientific evidence to show high its validity.
RE Technology: Technical performances/limitations and expectations 1. Mismatch between the new RE technology and the existing supporting infrastructure.	1. Biofuels is compatible with the hydrocarbon infrastructure and ICEs.	1. Biofuels implemented in the US and Brazil by the oil companies signified the applicability/practicality of these technologies. Biofuels are compatible with the existing hydrocarbon supply infrastructure and ICEs that allow the immediate adoption.
2. Competition between one RE technology with another RE.	2. No competition between biofuels and other types of REfT (H_2, electricity)	2. Since biofuels are compatible with hydrocarbon infrastructure and ICEs, biofuels have gained the global attention as the front runner. At this stage, there is no foreseeable competition of biofuels with others potential technologies like H_2/electricity. In fact these various options are seen as complementing each other, to power the entire road transport system for the near future. The emergence of new REfT after biofuels, could provide several choices for consumers, and gradually shifting the depleting hydrocarbon to low-carbon RE.

Institutional Interests and Involvements 1. Institutional vested interests which resists the further deployment of new technology.	1. Biofuels create multiple impacts on other industries	1. Due to socially shaped implications of biofuels adoption, biofuels could achieve the regulators' and corporate objectives, motivations and interests. The bottom line is, biofuels do not create any competition for oil companies under the same economic objectives. Besides, the implementation which could achieve respective public agencies' political agendas and bring positive implication for agricultural industry, environment, transport and economic planning. The 1G biofuels generates wealth on the agricultural industry. The NGB development magnetises the biotechnology institutions and the oil companies for profit seeking. Hence, biofuels create multiple positive impacts on other industries.

Source: Summarised by the researcher

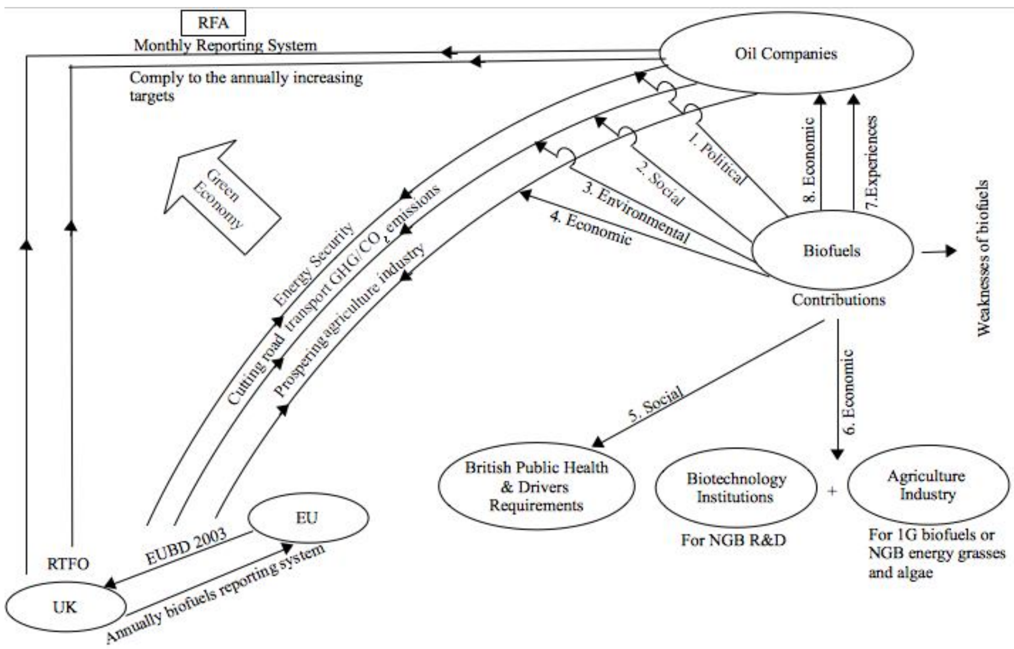
Table 7.2.2: Risk and Uncertainty and Strategies Applied by Oil Companies during the 1G Biofuels Deployment

Types of R&U	Strategies adopted	
	BP's approach	Shell's approach
Technology 1. Weaknesses of the current 1G bioethanol on -Low heating values -Low energy content -High water affinity (as discussed in appendix 7.1.2)	1. Biobutanol R&D with DuPont.	1. R&D for biogasoline with Virent.
Business operations: 1. G&S criteria of biofuels which is gradually being emphasised by regulators	-BP supplies biofuels according to the RTFO targets, and reports to the RFA monthly on biofuels carbon and sustainability in order to get the RTF certificate. -BP complies with the Meta and Qualifying Standards set by the RFA. -BP participates in various roundtables.	-Shell's internally established its Sustainable Sourcing Policy (SSP) -Shell supplies biofuels according to the RTFO targets, and reports to the RFA monthly on biofuels carbon and sustainability in order to get the RTF certificate. -Shell complies with the Meta and Qualifying Standards set by the RFA. -Shell participates in various roundtables.
Social/market acceptance on biofuels	-Utilise corporate websites and corporate videos to promote the benefits of using biofuels.	-Utilise corporate websites, corporate video and YouTube to promote the benefits of using biofuels.

Source: Summarised by the researcher

7.2.2 The Interplay of the Governments and the Oil Companies for the 1G Biofuels Deployment

Bringing together the stakeholders (regulators and oil companies): the driving forces/mechanisms to deliver biofuels deployment and the interactions generated, all of these have been previously discussed in sections one and two, is summarised/demonstrated in Model 1 as below.



Model 1: Summary of the Interplay of the Respective Stakeholders during the 1G Biofuels Deployment
Source: Summarised by the researcher

A. Between the UK Government and the EU Government

-The EUBD (2003) requires all member states to replace non-mandatory 5.75% (energy content) of all transport hydrocarbons with biofuels by 2010.

-The EURED (2009) requires all member states to adopt a mandatory 10% of energy used in transport to be renewable by 2020. This will expand the long-term use of biofuels incorporated as one of the REfT.

-The UK Government collects information from the RFA “Carbon and Sustainability” reports, and feeds-back to the EU annually.

B. Between the Governments and the Oil Companies

Table 7.2.3: Three driving forces of biofuels deployment

From governments	From oil companies
(a) Energy security	Energy challenge, towards energy security and fulfil increasing energy demand.
(b) Cutting road transport GHG/CO_2 emissions	Environmental concern in climate change, biofuels adopted as fuel option for road transport GHG/CO_2 reduction.
(c) Prospering agricultural industry	Prospering agricultural industry (BP)

Source: Summarised by the researcher

-The UK RTFO (2008): Sets annually-increasing-targets of biofuels blends with hydrocarbon. 2.5% in 2008/09, 3.25% in 2009/10, 3.5% in 2010/11, and 5% in 2013/14.
-Oil companies maintain the consistent supply for annually-increasing-RTFO-targets of biofuels blends with hydrocarbon, to comply with the European Standard of biofuels-biodiesel EN 14214 and bioethanol EN15376.
-New sets of regulatory establishment. The RFA requires oil companies to submit a "Carbon and Sustainability" report every month to the agency on biofuels data, with an emphasis on the G&S biofuels criteria.
-As a reward for this reporting system, the oil companies would be awarded with the RTF certificate-which acts as a licence for biofuels supply and trade.
-Biodiesel and bioethanol are taxed at 20p/litre less than petrol and diesel.

C. Social Implications of Biofuels Adoption
1. political: towards energy security, transition from a hydrocarbon-dominated-economy to a green economy. Biofuels adoption is the quickest/effective way to cut GHG/CO_2 emissions, so that the UK could comply with the EU/UN mandatory on GHG reduction targets.
2. social: better public health due to lower air pollutions, and combating climate change-which is a global concern.
3. environmental: cleaner air with lower air pollutions, reduced GHG/CO_2 emissions. Biofuels have less negative impacts on the environment because they are biodegradable.
4. economic: transition from a hydrocarbon-dominated-economy to a green economy by creating more employment opportunities along the value chain/activities of biofuels farming, production, supply and trade.
5. Impacts on drivers (biofuels user)
(a) safer for drivers in reducing incidents of vehicles on fire, due to biofuels' lower flash point.
(b) better fuel economies for consumer and cost savings due to lower evaporative emission.
(c) effective CO_2 reduction due to biofuels' natural carbon neutrality.
(d) effective in cutting CO_2/GHG (2.5-4% for 5% use) from vehicle tailpipes.
(e) reduce air pollutants[229]
(f) conformance blends with the ICEs, which does not require personal investment in ICE modification.

D. The 1G Biofuels Deployment and the NGB Development
6. Economic link to a prospering agricultural industry. Create profit seeking links with biotechnology institutions (academic and commercial institutions)

E. Industrial Pragmatism of Biofuels Adoption
7. BP is supplying biofuels in the US and Shell is supplying biofuels in Brazil, provide a convincing/proven experience on the practicality of biofuels adoption.
8. Biofuels as an economical option:
(a) Biofuels are compatible with the existing hydrocarbon infrastructure (storage, supply and

229 benzene, NO, NO_2, CO, CO_2, lead ambient, aldehyde, SO_2, Sulphates, Particular matter, aromatic and low carcinogenic compounds.

distribution). This provides an immediate executability with lower switching costs, as no new infrastructure is required for biofuels blended supply.
(b)Biofuels using biomass (the sugarcane[230], the NGB biomass) and also the NGB on wastes (animal fats, tallow and used cooking oil) moving towards recycling and reducing composite wastes.

F. Weaknesses of the 1G Biofuels which need to be resolved in the NGB development
(a)Bioethanol has lower heating values which generates lower energy content. It provides only 67% of the energy compare with petrol. Therefore it is not fuel efficient to the motorists.
(b)Bioethanol shows a high water affinity which causes the components of ICE to rust. This could lead to a lower social confidence with a higher percentage blend of bioethanol use.
(c)Biodiesel has strong solvent properties to natural rubber and soft plastic in ICEs. This could jeopardise the ICE components and lead to lower social confidence with a higher percentage blend of biodiesel use.
(d)Fermentation and transesterification processes which are slow, inefficient and with high production costs.
(e)The low capacity of biofuels which are derived from foodstocks and waste products will face a bottle neck of sustainable supply. This can cause failure in fulfilling the increasing future demand. To enhance productivity, new feedstocks from the NGB with higher yields are required.
(f)The carbon cycle-from growing feedstocks to burning biofuels in the fuel tanks, would achieve near carbon neutral-if the activities along the value chain are fully integrated to minimise the CO_2 release. However, there is no universal true for all biofuels types. The emission reduction from biofuels is varied depends upon the types of feedstock. Therefore biofuels types, land use and all activities involved along the value chain must play their part in the biofuels carbon equation.

7.3 The Emergence of Systemic Risk

Looking at Model 1, the setting for the 1G biofuels deployment portrays the encouraging context for the ease of the UK biofuels implementation. It was easy to assume that, the expected R&U were drastically reduced by the mechanisms and strategies put in place, to encourage biofuels adoption and to achieve the targets set by the RTFO. Yet, two months after the activation of the RTFO, biofuels' credential and social benefits were questioned by the international/local pressure groups-such as social movements[231], and environmentalists[232]. The scenario was further amplified by the international/local broadcasting/print/internet media. The reason was, the 1G biofuels deployment had created two systemic risks: food-fuel competition and biodiversity threatened (refer appendix 7.3.1).

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230 Sugarcane plant residue, or bagasse, is reused to generate heat and electricity, making the process more cost effective and environmental friendly. It provides 90% of carbon saving compare with petrol from well to wheel basis.
231 Also called the Learned Society such as: The Royal Society, British Academy, The Royal Academy of Engineering, The Royal Environmental Health Institute of Scotland and The Agricultural Economics Society.
232 Some of the eloquent international/UK pressure groups. Action Aid, Carbon Trust, Energy Saving Trust, Forum of the Future, Friends of the Earth, Green Alliance, Greenpeace, Low Carbon Vehicle Partnership, Oxfam, and the Royal Society for the Protection of Birds.

(a) Food-Fuel Competition

Biofuels production distorted the food markets in two ways. Firstly, due to high biofuels global demands, this provided a more lucrative business opportunity than growing crops for food. According to Mitchell (8 April 2008; 2008), the US expanded its maize area by 23% in 2007, in response to high maize prices and the rapid demand for maize bioethanol. This resulted in a 16% decline in soybean area, which reduced the soybean production by 19% and contributed to a 75% rise in world soybean prices between April 2007 and April 2008. Besides, the European farmers were also cutting back on wheat, in order to plant rapeseed/oilseed crops for biodiesel. The eight largest wheat exporting countries[233] expanded their rapeseed and sunflower growing area by 36% between 2001-2007, which caused total wheat area fell by 1%.

Secondly, there were cases discovered, whereby large quantities of grains were converted to produce biofuels. Commented by Vidal (22 January 2010), 1/3 of all the maize and other grain crops grown in the US ended up as biofuels in cars. Therefore, these two factors had caused international food supply shortages, pushed up food prices, and resulted in world hunger (BBC News, 23 March 2007; Vidal, 15 February 2010). Mitchell (8 April 2008; 2008) concludes: "Biofuels have forced global food prices up by 75%. This figure emphatically contradicts the US government's claims that biofuels contribute less than 3% to food price rises."

(b) Biodiversity Threatened

Biodiversity has been reduced by the intensification of biofuels crops as mono-cropping practices, which guaranteed by the increasing global market demand for profitable prices. Changes in land use have reduced diversity with the conversion of more wetlands/forests/jungles into large-scale fuel crop plantations. Supported by Atkins (1 September 2010), rainforest and wildlife in South East Asia are being lost in the US/EU drive for biofuels. The habitats of the orang-utan and the Sumatran tiger are being trashed in Malaysia and Indonesia to make way for palm oil.

233 The EU, China, India, US, Russia, Canada, Pakistan and Ukraine (FAO, June 2009).

Furthermore, Kenneth Richter-from Friends of the Earth said: "Massively expanding sugarcane plantations to produce biofuels has significantly threatened Brazil's rainforest. The biofuels industry is pushing agricultural activity on forested land where trees are cut down to make space for fuel crops farming" (Mathiason, 1 February 2010).

7.3.1 Confluence of Factors Rendered to the Emergence of Two Systemic Risks

(a) Political Rush for Biofuels Deployment

From the pressure groups point of view (BBC News, 29 June 2007; 24 March 2008), those regional/national biofuels policies were running ahead of biofuels' science and technology, which caused the 1G biofuels has failed to provide a sustainability supply. In reality, what made these policies ahead of science and technology capacity was mainly due to the political rush by the regional/national regulators. Looking at this issue chronologically, we can obtain more evidence to understand what have caused such political haste.

The EU and its member states ratified the Kyoto Protocol in late May 2002. The EU was committed to a legally binding target-whereby it has to achieve 8% GHG reduction by 2012. The period from 2008-2012 is called the first commitment period, and the EU has to work on the three largest GHG polluters: power generation, transport and energy consumption from households, manufacturing and commercial.

In 2003, the EUBD was adopted. Although a non-mandatory biofuels target 5.75% was set for 2010, an intermediate target of 2% by 31 December 2005 was also set. As a result, the EU25 (25 member-states) collectively achieved 1.4% in 2005[234]. The UK officially launched the RTFO on 15 April 2008, initially set biofuels targets of 2.5% (2008/9), 3.75% (2009/2010) and 5% by 2010 onwards. Looking at these

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234 with Sweden led the position (3%), followed by Austria (2.5%), then Belgium, Estonia, France, Germany, Latvia, Lithuania, Portugal, Slovakia, Spain (each 2%), while the UK only achieved 0.2% (European Commission Energy and Transport Directorate, April 2006).

targets, the gap between each target is more than 1%. This demonstrates, the urgency of the UK Government to catch up/comply with the EUBD 5.75% by 2010. Knowing that the NGB would only be commercially available within five-to-ten-years from 2008, the 1G biofuels derived from food had been activated. The desperation to attain the various regional/national targets resulted in tunnel-vision within regulators and caused them to overlook numerous obstacles along deployment process. Consequently, the political rush led to the emergence of these two systemic risks.

(b) Inadequate Risk Assessment from the Socioenvironmental Dimension

The emergence of these two systemic risks depicted the pre-assessment, appraisal, evaluation and management of R&U advocated by Renn's Risk Governance (2008) (refer literature section 2.6.2), particularly along the biofuels implementation process was inadequately assessed. This was because, the previous mechanisms in place were too focused on how to commence the 1G biofuels and how to achieve the RTFO targets as the ultimate objective. They had not consolidated risk precautionary principles within these mechanisms/strategies, which should have considered the socioenvironmental implications before biofuels deployment.

The regulatory approaches were focused too much on limiting false positives. Explained by Page (1978) (refer literature section 2.7.5), the conventional political decision assumes that, any new technology like biofuels is safe/beneficial until proven otherwise. Yet, when any negative outcome is detected (two systemic risks of the 1G biofuels deployment), the damage had been done and the consequences were irreversible. Furthermore, the methodology of policy making has failed to address the implications of differences in the distribution of benefits and costs; especially when victims are exposed to the systemic risks but have not received a commensurate proportion of the benefits from biofuels adoption.

The EU/UK published policies backed the 1G biofuels execution, by stated clearly their readiness to have this technology deployed. Most of the strategies to mitigate the R&U were focused largely at the technical aspects of biofuels, such as quality standardisation and incentives provision, as the preparations before biofuels commencement. There are two features of a successful RE policy that suggested by Mallon (2006) on land use planning reform and equalising the community risk and cost-benefits distribution were seriously neglected. Although the RTF certificates are issued to suppliers (RTFO Order, 2007) which acts as a control mechanism for biofuels suppliers who have complied with the RTFO targets, the G&S criteria was not enforced rigorously as the priority.

Supported by some evidence whereby the G&S criteria of biofuels have not been fully established by the RFA, even after the implementation of the RTFO on 15 April 2008. Many roundtables were busy formulating sustainability Principles and Criteria (P&C) in the early years and have these P&C established in 2009-which was more than a year after the commencement of the RTFO, and six years after the EUBD 2003 adoption. This showed the concerns of the G&S biofuels have been seriously neglected. Indeed it was unacceptable to have the EUBD/RTFO commenced, without having the P&C properly instituted beforehand by the EU/UK public agencies[235]. Inevitably, there was an impairment to look merely at one side of the coin, trumpeting the face value of biofuels on the social, economic and environmental gains, while ignoring the potential negative impacts on socioenvironmental losses. A good RE policy should be equipped with ten key features (refer literature 2.3.5) advocated by Mallon (2006). It is unwise to wait until problems emerge before seeking for solution. It would have been reasonable to expect that even a lay person would ask: “Producing biofuels from food, what will happen to our food? What will happen to our land?” If these issues have been seriously considered, then, the systemic risks on food-fuel competition and biodiversity threatened could have been prevented from happening.

(c) Different Social Context for Biofuels Adoption

Initially, biofuels were developed and tested in laboratories for their applicability.

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235 associate with the EU/UK environmental, transport, agricultural industry, rural development and RE agencies.

They were adopted in the US and Brazil and have been in domestic use for a number of years. However, biofuels which are successful in one social context have caused some serious problems in the UK.

One of the main factors is that the UK could not produce an adequate supply of biofuels to enable greater self-sufficiency as the US/Brazil does. Even two years after the RTFO execution, the UK only produced 17% biofuels for its domestic use, while 83% of biofuels were imported through international trade[236] (RFA, 2010). Although the UK relied on its home wheat and oil seeds surpluses, the food-fuel competition still arose and resulted in domestic food price increased. Since the UK is dependent upon the imported biofuels, the UK is also responsible for the occurrence of these two systemic risks that arose in those exporting countries. Furthermore, the transportation of biofuels through international trade adds up the global GHG/CO_2 emission. Even though this issue has not been tackled by the regulators as at the time of writing, it should be considered in order to achieve a more comprehensive GHG/CO_2 saving.

Despite the scientific testing on the 1G biofuels has showed the applicability of this technology, the results in a laboratory do not reflect the real life context. Biofuels which are applicable to one social setting could not be generalised for other social implementation. Due to the fact that, there are different constraints imposed by local environmental factors, with different sets of rules and regulations, different institutional participations, a diverse culture, and differing objectives for biofuels adoption; all of which make the implementation complex/challenging.

(d) A Limited Domestic Production Capability versus the Unlimited Global Biofuels Demands

Two of the world largest biofuels producers-the US and Brazil have contributed to the spreading of two systemic risks. The US has pushed too far on its biofuels

236 From 15 April 2010 to 14 July 2010, the UK produced 12% biodiesel and 24% bioethanol for its domestic market. Argentina contributed 34% biodiesel to the UK, while Brazil contributed 30% bioethanol (RFA, 2010).

production capacity. Although the Brazilian sugarcane did not contribute to the food-fuel competition[237], the Amazon forest has been intruded to give land for more sugarcane plantations. What we can see from both examples is that: when biofuels were expanded from a home-grown cycle of self-sufficiency to cater for an unlimited world demand, the elasticity of their domestic productivity is finally ruptured. The 1G biofuels quantity was far below the theoretical expectations to fill the gap caused by the increasing demand. This indicated overconfidence in the technology and the false positives preconception, which has ignored the natural limitation of food-derived biofuels production, while underestimated the principles of locality, geography and weather- that are directly influenced the yield of the 1G biofuels. Consequently, the food security and ecology became the victims for the greed of global biofuels businesses. Explained by Thomas (2007), although many see biofuels as a way to avoid the oil wars currently raging in the Middle East, going down the biofuels road may in the end provoke a wider series of resource wars: food, water and habitable land. This trend shows the prematurity of policy makers to put so much emphasis on biofuels, rendered to the emergence of two systemic risks.

(e) Biofuels Producers/Suppliers Eyeing the Economic Gains

Stigler (1971) and Peltzman (1976) explain that, business lobbying is a form of advocacy, whereby the business firms organise themselves into groups, with the aim to influence and shaping future regulations in order to protect/enhance their profits. Recall the supportive statements made by the regional/national farmers and biofuels producers (reported in the media), their forceful messages were justified for regional/national biofuels adoption. They stressed the surpluses of the grain productions which could be value added, if they were converted into biofuels.

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237 Mitchelle's (8 April 2008; 2008) report points out that biofuels derived from sugarcane, does not have a dramatic impact on food prices. This is because Brazilian sugarcane production has increased rapidly, and sugar exports have nearly tripled since 2000. Brazil uses approximately half of its sugarcane to produce ethanol for domestic consumption and for export; while the other half is used to produce sugar. The increase in cane production has been large enough to allow sugar production to increase from 17.1 million tons/year to 20.6 million tons in 2007. Brazil's share of global exports increased from 20% in 2000 to 40% in 2007.

According to Matt Ware-the Policy Advisor of the National Farmers' Union: “We produce three million tonnes of surplus a year. Figures show that we currently have enough surpluses to produce 5% bioethanol” (BBC News, 18 April 2006). Furthermore Peter Kendall-President of the National Farmers' Union commented: “British farmers can meet the nation's demand for both food and fuel crops. The UK agricultural sector already has enough capacity to fill fuel tanks and dining tables. 3.5 million tonnes of wheat surplus will account for the bioethanol. Using the UK's 750,000 hectares of set aside to grow oilseed rape will comfortably take care of the biodiesel requirement,” (BBC News, 5 October 2006).

For the benefit of the products added value, more jobs were created and prospered the agricultural sectors. Consequently, the 1G biofuels obtained the green light to be the front runner in the EU/UK. However, the reality was, during the effectuation of the RTFO, the empty talks of grain surpluses burst like bubble. The nation was awaken by the emergency call to slown down the biofuels expansion. The consumers realised the profit making agendas og the agricultural industry, and the effect of using food to burn in vehicle engines, resulted in domestic/international high food prices. The pressure groups began questioning whether there were there any genuine grain surpluses. If the answer was yes, then why just after two months of the RTFO implementation, did the high food prices strike the nation? The situation was further aggravated by evidence broadcasted by the BBC News on 22 April 2008 that the global price of wheat has risen by 130% during 2007 to March 2008.

“Political leaders seem intent on suppressing and ignoring the strong evidence that biofuels are a major factor in recent food price rises. While politicians concentrate on keeping industry lobbies happy, people in poor countries cannot afford enough to eat,” said Robert Bailey-the Policy Adviser at Oxfam (Chakrabortty, 3 July 2008). The food markets have been distorted as we observed the profit seeking motives of the biofuels farmers/producers/suppliers, who have robbed the domestic/international food security for the sake of fulfilling biofuels’ increasing demands. Although sufficient/suitable land is probably available for biofuels crops growing; yet, according to Gallagher (2008), the current policies have failed to ensure that additional production occurs in these areas. Invasion of farms and high biodiversity areas have happened to give way for biofuels crops.

7.3.2 Institutional and Power Shift after the Systemic Risks Emerged

The international/local communities have been awaken by the implications of the two systemic risks. More and more outspoken international/national/local social movements and environmentalists have eloquently criticised the EU/UK regulators' decision on the 1G biofuels adoption. They actively attacked the biofuels deployment process and publicised their views-which were mostly against biofuels implementation. With the power of their own organisational media-mainly their website, printed handouts and the public activities they conducted such as talks, seminars, campaigns and calls for demonstration238; all of these activities have been coordinated at different levels-from local communities, national, and up to international level.

As well as the pressure groups making their voice heard, the UK's domestic broadcasting[239]/print[240] media were also playing a proactive role in the controversy. They were not only broadcasting their analysed news (from their own journalists/correspondents), but also cross disseminating/reporting on news/information/reports from the international/national social movements and environmentalists. They organised events like forums, made their own investigative TV[241]/radio shows and broadcasted the experts and public's views/concerns. Both pressure groups and broadcasting/print media have amplified the systemic risks further, thereby heightening public anxiety, pressuring on the regulators/biofuels stakeholders, and vilifying the consequences of biofuels adoption.

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238 This could be found on a website, Biofuels Making the Climate Crisis Worse, Not Better, with many demonstrations and campaigns against biofuels expansion. The groups have gathered the British public to demonstrate in front of the UK Parliament and the Scottish Parliament.
239 BBC, ITV Network, RTL and Channel 4 TV.
240 Guardian, Financial Times, Telegraph, Independent and The Economist.
241 The BBC has made a investigative documentary about biofuels titled: "The Great Green Fuel Gamble", broadcasted on BBC 2, Friday, 14 March 2008.

To express my observation from April 2008 to September 2008: Apart from the existing well-known pressure groups, there were more and more local/small-scale/new pressure groups were established (religious groups, human rights) sprung up like mushrooms after the rain, and they were everywhere and working like an army of ants. They were vocal. I read, hear and watch them in the print/internet media and seminars organised, mostly condemning biofuels. Biofuels ranked in the top ten searched topics of many search engines like Google, yahoo and MSN for nearly two months. I hardly heard/read any positive comments about biofuels through the broadcasting/print media from these pressure groups. The joint forces of the broadcasting/print media and the coalition amongst these pressure groups were powerful and vocal. Biofuels causing "food prices increased", and "environment destroyed" were two of the slogans which I could hear everywhere, repetitively, and supported by more and more evidence as the days passed.

The two systemic risks and heighten public anxiety made the R&U more complicated with a higher degree of uncertainty remained. According to Klinke and Renn (2002), to deal with risk which is highly uncertain, RM needs to incorporate hazard criteria, and pursue a cautious strategy that enables learning by restricted errors. The main philosophy for managing these R&U is to allow containment approach that enable risk to be stopped or the process could be reversed. In order to respond to the heated biofuels controversies, a rescue work like a "fireman to put out fire" had taken to rectify the situation. The risk mitigation strategy-advocated by Dorfman (1997) is adopted to fix the flaw by providing control to mitigate the impact associated with the flaws.

This was evidenced by the publication of the Gallagher Review (2008) (refer appendix 4.1.5), and the alteration of the RTFO targets[242] in order to slow down

242 The initial RTFO required the UK's transport fuel suppliers to ensure 5% of all road vehicle fuels supplied are from biofuels by 2010. However these targets have been modified after Ruth Kelly's statement broadcasted on media, which subsequently supported by the Gallagher Review published in July 2008-rendered the amended targets to 2.5% in 2008-2009, 3.25% in 2009-2010, 3.5% in 2010-2011, while 5% in 2013-2014.

biofuels expansion. Besides, the EU/UK Governments began to emphasis the G&S criteria/requirements of biofuels. A more stringent biofuels "Carbon and Sustainability" reporting system is put in place which controlled by the RFA, in order to ensure that biofuels used within the UK comply with the G&S criteria of the RFA Meta/Qualifying standards, and to ensure higher transparency of biofuels information can be reported from biofuels suppliers (oil companies).

Both BP and Shell responded to the governments' G&S biofuels production/production, by providing more detailed and higher transparent biofuels data when reporting to the RFA. Since the RTF certificate includes the G&S criteria (apart from the compliance of annual target), both companies are working to comply with the Meta/Qualifying standards outlined (refer appendix 7.3.2). Simultaneously, the organisational media owned by the regulators and the oil companies (mainly websites, online corporate videos and public reports[243]) were concentrated in disseminating "below the line" content (refer appendix 2.7.1)-which intentionally to arouse more positive feelings in rebuilding public confidence/acceptance on the continuation of the 1G biofuels implementation after the occurrence of these two systemic risks. More information about the NGB R&D projects was introduced, to promote the G&S criteria/benefits of the NGB.

The UK Government's reactions were quick, and had the desired effect of calming the public outrage and reassuring them as to the future of biofuels. The pressure groups took the RTFO targets changed as a victory which was published through their organisational media, and reflected in activities they organised. Although food prices remained high, they were at least under control, and no further price increases were detected (reported by the broadcasting/print media). The most important event that helped to cool down the controversy was the shift of the international/national broadcasting/print media attentions-away from biofuels to the world financial crisis,

243 For example, the DfT report (2009a, 2009b) to highlight the importance of sustainable development and protecting environment that embedded within the national transport system. The DfT (2010b) UK Transport and Climate Change Data to link with the contribution of biofuels in carbon saving.

in an aftermath of Lehman Brother bankruptcy[244]. Since then, the strength of biofuels systemic risks amplification has halved. The pressure groups continue their agendas with the ultimate aim to abolish the grains-derived-1G biofuels, but also advocating more use of recyclable organic wastes, and behaviour change on personal transport (such as more public transport use, cycling, walking and car-sharing) while the broadcasting/print media were keen to follow up the global recession which has a higher news value.

Looking at the bigger picture, these two systemic risks, not only have caused the subsequent biofuels implementation to be more difficult, but they have also created an opening for the pressure groups/media (watchdogs) to monitor on biofuels deployment. There was a significant institutional and power shift, whereby previously the authority was mainly confined to the regulators and the oil companies under the context of regulated market. Due to the power of the media and the pressure groups, their representations for general public's socioenvironmental concern no longer can be ignored.

Furthermore, some of the internationally recognised social movements and environmentalists are holding their memberships in various biofuels roundtables (refer appendix 7.4.1) to design biofuels G&S criteria/requirement. There was a substantial pressure from these social groups on the regulators, to have the G&S criteria on biofuels products, production and supply to be lawfully enforced. Such requirements not only will change the existing biofuels supply chain-by prioritising the socioenvironmental sustainability, but also will shape the NGB product and production criteria/requirements legitimately.

7.3.3 Building Social/Market Acceptance on Biofuels through Organisational Media

Reflecting back to the period of biofuels controversy, although the British public had

244 16 September 2008 marked the beginning of world financial crisis 2008/10, after the Lehman Brother bankruptcy has been broadcasted worldwide (BBC News, 16 September 2008).

not seen the tangible results of deforestation/land change-as they happened in the developing/biofuels exporting countries; the expensive food prices has inflamed the public emotions. Many of the disputed issues were resulted by the media amplification or based on hear-say and word of mouth. Although many environmentalists rejected biofuels adoption, many did not adequately provide/suggest better solutions in reducing the GHG/CO_2 emission from transport system.

The Governments, BP and Shell did not launch a direct confrontation/media war with the pressure group. Strategically, they disseminated facts and the NGB information through their organisational media[245], by corporate activities like Shell's webchat, and biofuels expo[246]. Due to the wide spread of information was largely based on individual and institution perceptions, a polarised view on pro-or-anti biofuels were rooted. The information published by the governments and the oil companies was perceived to be biased by some of the communities.

To balance the debate, there were some independent and reputable internationally recognised organisations like WorldWatch Institute, The UK Royal Society, European Biodiesel Board, and paid subscription publishing companies like Nature.com and free subscription publications from Biofuels Digest (refer appendix 7.3.3); were acting as unbiased scientifically knowledgeable broadcasters. Through periodical publications, they published the latest information about biofuels and sought to educate the general public with the latest biofuels technology and findings. These independent and esteemed organisations/learned societies, were acting as the educators by distributing the biofuels knowledge to the general public, and complementing publications from the oil companies and the governments. They provided a more comprehensive overview from the scientific angle about biofuels. Crucially, they do not represent any policy makers, and they are not the mouth-piece

245 Print media like reports, or downloadable electronic reports and press releases. Electronic media like YouTube, websites and corporate videos.

246 BP participated in the European Biofuels Expo and Conference 2008. Meanwhile Shell participated in the Biofuels International Expo & Conference 2009.

of the oil companies/biofuels players. The information published by them was factual and backed up by research. There were criticisms on the 1G biofuels, disagreements on government policies; yet, there were also positive messages to promote the G&S criteria of the NGB. Therefore information/publications from these organisations were balance and carried more weight for validity and reliability. From these scientifically enriched publications, the public could gain more information and to understand the debate further, rather than relied on the simplistic opinionated publications issued from a pro/anti biofuels.

7.3.4 Empirical Suggestion for Social Shaping Technological Related Risk

It is acknowledged that there are different approaches to the concept of risk (refer literature table 2.5.1). Although Denney (2005) has made a comparative study amongst these theoretical positions of risk, the concepts mainly contribute to the understanding of the definitions, classifications and types of risks. The richness of social construction of risk is centralised on the role of actors and cultural influences, which is in the construction of their perceived risk reality. Denney (2005) explain, the socially constructed risk advocates that the "risk perceptions" are socially constructed, while the pervasiveness of the risk consequences is takes place through social interaction. Therefore, what seem less obvious are the causal factors which result in technological related R&U.

The conventional causal factors of technological risk mainly criticise the mismanagement[247] of stakeholders, either intentionally/unintentionally violated the safety factors at design, testing, execution process, R&D and disposal which caused R&U to happen (Girmvall et al., 2009; Evan and Manion, 2002). Meanwhile, this research points out, both the systemic risks which stemmed from mismanagement[248]

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247 careless, mistakes, intended sabotage, irresponsible attitude, unqualified, beyond the capability of planning/forecasting and lack of preventative actions.
248 Some evidence for mismanagement (refer 7.3.1b,c,d) show that, there was an inadequate assessment of socioenvironmental consequences, and disregarded the issue of locality and imbalance between agricultural capacity against global biofuels demands.

and the stakeholders' interests[249]. Apart from the interests of the regulators and the biofuels players[250], the pressure groups emerged have also manifested their interests to lobby for socioenvironmental safeguards. The activities they organised and the information broadcasted through media, have amplified the systemic risks further which caused more public anxiety. Despite the fact that, the requirements to enforce biofuels G&S criteria strictly could protect the socioenvironmental benefits, these new understanding has put added pressure on the regulators/biofuels players to deliver the G&S compliance, and consequently has increased the costs of policy and management actions.

The findings of various stakeholders' interests in shaping technological related R&U is an extended understanding from SST. In this respect, there are strong resonances between SST and Social Shaping Technological Risk (SSTR). SST refutes that technology is developed according to an inner technical logic. Instead, technology is a social product, which is patterned by the conditions of its creation and use (Williams and Edge, 1996). Extended to SSTR, since technology is a social product, the technological risk does not develop from a technical logic. Instead it is shaped/influenced by intricate social forces and the social network involved. Thus SSTR explains "how" and "why" the R&U could occur during the technology design, adoption, operation, innovation and termination, which these activities are parallel to SST processes.

As such, to analyse SSTR means to analyse the influence of organisational, political, economic, social and technology in shaping risk. SSTR means identifying different types of risks[251] through different theoretical positions; at every stage[252] of a new technology, asking what are their causal factors resulting in such risk occurrence.

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249 Refer 7.3.1 a and e. They explain the regulators' political rush and biofuels farmers/producers/suppliers profit maximisation, have the agricultural limits been overly stretched.
250 biofuels farmers, biofuels producers, biofuels suppliers and biofuels traders.
251 From risk characterisation and evaluation to identify whether: individual/large-scale (systemic) risks; expected (low uncertainty)/unexpected (high uncertainty) risks; acceptable/tolerable/intolerable risk (HSE, 2001); linear/complex risk.
252 the design, adoption, operation/implementation, innovation/development and termination.

Thus, we may use the label of SSTR to designate an alternative approach to the risk study, and signify a set of counteracting strategies that share the following sets of assumption and concern:

(i) SSTR explores the social processes relating to different types of risk generation.

(ii) Negotiations, interactions and decision-making processes among different social groups (actors) are a focal point, emphasising concepts like varied interpretations of risk[253], with their perceptions, respective interests which produce R&U, and the counteracting strategies. This is where the risk governance analysis from Renn (2008a) is required.

7.3.5 Empirical Suggestions for Converged Regulator and Public Risk Perceptions

According to Sjoberg and Drottz-Sjoberg (2008), the regulators and the public's risk perceptions are varied across a range of different risks studied. Normally, the general public perceives a greater risk than the regulator (refer literature 2.7.4). Examining the systemic risks created through the 1G biofuels implementation, the research points out that, the risk perceptions were different between governments and the public. This was mainly due to each of their own perceived risk, and not the risk they estimated others to perceive. The governments tended to base on their policy attitude. They feared the failure to achieve the mandatory GHG/CO_2 reduction targets and biofuels targets; but not the views that the public had fears of food security and ecology protection. The regulators believed that they had the mechanisms instituted (messages projected through respective EU/UK biofuels policies), to facilitate biofuels deployment whereby most of the anticipated R&U were within control. Furthermore, the regulators perceived the benefits[254] that arise from biofuels adoption. However, after the systemic risks arouse, the public did not buy in these benefits, when the traded-off were high food prices and a destroyed ecology. In the end, pressured by social groups, the regulators and the public risk perceptions were

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253 Constructivism/realism of risk; interpretive/normative ambiguity (Renn, 2008); decision makers/stakeholders versus public risks perceptions (Sjoberg, and Drottz-Sjoberg 2008).

254 GHGs reduction from road transport, job creation, prospering agricultural sector and for energy security.

finally converged. The regulators priorities were found to match those of the public and the pressure groups concerning the enforcement of the G&S biofuels products, production and supply. Yet, we have seen a delayed in such risk perceptions convergence, which should have happened earlier, in order to reduce the damage cause by the systemic risks, or it may have avoided them from happening.

In order to have the converged risk perceptions built earlier, risk governance advocated by Renn (2008) is helpful. A pre-assessment to obtain public opinions/responses should be made in any stages along the decision-making and decision-execution process by the regulators. According to Renn (2008b), this could help to learn about public values/concerns, in order to detect new/emerging R&U while to provide some initial insight into the extent/severity of these R&U. The risk information collected from the assessment could be pre-screened and allocated to different management routes. Even though we could not expect both the public and the regulator's risk perceptions would come together at the early stage; listening to the public worries[255] and establishing risk communication[256] channels (two-way communication) would be highly recommended. This is to avoid the disparity between the regulator's and the public's risk perceptions, which subsequently could avoid the emergence of unexpected R&U. In fact, the core responsibility for the regulator is to safeguard the socioeconomic and socioenvironmental benefits for its general public under the public order. Any political decision made to enact policy formulation/execution has to be based on that rule of thumb. After years of stressing the need/benefits[257] for two-way communication; yet, this practice has still not been widely implemented. From this research, it seems to fit in the belief that, the biofuels policy had been determined in advance among the regulators and the biofuels

255 getting information from broadcasting/print media, discussing with the social movements/environmentalists, conducting a public survey before the commencement of biofuels.
256 Set up a platform like interactive homepage which allows the public to leave comments/feedbacks, a telephone hotline, campaigns to answer public queries, or collecting public opinions through survey.
257 The benefit of two-way communication (between the general public and the regulators), according to OECD (2002), is to build up a mutual trust by responding to the concerns of the public and the relevant stakeholders. Besides, this could also assist the stakeholders to understand the rationales of risk assessed results, and to arrive at a balanced judgement that reflects the factual evidence about the matter in hand with relation to their own interests and values.

players, regardless of any public participation. This missing gap between the regulators and the public was one of the cracks which allowed the systemic risks to be slipped in. Therefore, the research highlights, it is improper if public views/values have not been taken into account within the political processes of decision-making and decision-execution.

7.3.6 Empirical Suggestions for Public Interest Prioritisation

Biofuels mean differently to different stakeholders involved-as they perceive biofuels from the respective knowledge and interests. Due to the different interpretations, which are then being conceptualised as different values and purposes; all these varied values result in some stakeholders being into agreement while some end up with conflicting interests. This is where the R&U might arise. Table 7.3.1 (advocated by Fischer 2004, refer appendix 2.7.3) illustrates the differing opinions taken by protagonists in the debate on biofuels adoption.

Table 7.3.1: Different Standpoints on Biofuels Discourse

Underpinning logic behind position taken	Types of biofuels discourses
Ideological Choice (Because of)	Environmentalists/Social Movements: Irresponsible manipulation of nature for corporate profit and political gains, with evidential food-fuel competition and biodiversity threatened. Short-term effects-two systemic risks have spoken. Call for stringent G&S biofuels criteria to be legally enforced on biofuels products, production and supply; as well as extend the criteria to the NGB, in order to ensure the two systemic risks are resolved once and for all.
Systems Vindication (Because of)	Industry economists, oil companies, biofuels farmers/producers/traders/suppliers and biotechnology experts: A renewable criterion of biofuels is attractive. Biofuels help to increase the overall fuel supply towards fuel security (to fulfil an increasing demand since oil is a depleting resources), reverse the damage from climate change through road transport GHG/CO_2 reductions and generate a wealth creation for agricultural sectors. Biotechnology should be seen as part of energy and environmental modernisation. The NGB which is green and sustainable would be developed through biotechnology.
Situational Validation (Because of)	Department for Environment Food and Rural Affairs experts assured the aspects of biofuels introduction from domestic agricultural industry which correlates with the wealth creating opportunity for the economic growth. Besides, Department for Transport aims to cut the GHG/CO_2 emission from road transport system. The RTFO targets are bottoms-up biofuels blends targets, mandatory require annually-increasing-targets from 2.5% in 2008/9 to 5% in 2013/14.
Warrant (since)	Risk Analysts (before biofuels commencement): Guided by EU Biofuels Standards for existing ICEs adoption. No harmful effects are found due to high compatibility of biofuels with hydrocarbon on the infrastructure (oil companies), ICEs (automobile users), efficient for cutting GHG/CO_2 on road. Besides, the

	warranty provided by automobile manufacturers gave a confidence boost for automobile users in adopting biofuels. Risk Analysts (during biofuels deployment): Gallagher Review (2008) concludes that, the UK should not abandon biofuels as part of the low-carbon transport fuels. However, the G&S of biofuels criteria have to be facilitated for product, production and supply through oil companies/biofuels suppliers. Consequently, the monthly "Carbon and Sustainability" reporting system that managed by the RFA continues to emphasis on a higher transparency of biofuels data from the suppliers, while stringent G&S criteria have been gradually imposed. The biofuels targets have to be altered, which postpone 5% to 2013/2014 instead of 2010.

Source: Modified from Fischer (2004) by the researcher

This research points out that the environmentalists/social movements took an ideological standpoint which rejected the 1G biofuels for the reasons of socioenvironmental protection. The industrial economists, oil companies, biofuels players and biotechnology experts vindicated the benefits that biofuels may accrue. Departmental experts assured the positive aspects of biofuels introduction from an agricultural aspect-job creation, value added on agricultural products, as well as GHG/CO_2 reductions from road transport. Risk Analysts viewed the problem/risk as an issue of execution, measurement of the risk and an assessment of whether the risk level is acceptable, therefore biofuels deployment continuous.

As evidenced before biofuels commencement, the regulators decisions were largely influenced by the interest/pressure groups. Initially, the business interest groups (the oil companies, the risk analysts and the biofuels players) influenced the regulators to commence the 1G biofuels. However, after the two systemic risks occurred, the pressure groups (the international/national environmentalists and social movements) emerged. Their interpretations/perceptions on the systemic risks were in conflict with the regulators and the business lobbyists. Therefore, this scenario matched the theory advocated by Self (1985), Wilson (1990), Hood et al. (2004b), whereby the government's response is driven by interest/pressure groups (refer literature section 2.7.3c). The difference between these individuals was not the estimates of the risks, but the values and belief systems, there were dissonant amongst the protagonists. It is frequently the case that there is hardly a unanimous agreement achieved among the different parties. According to Jaeger et al., (2001), when decision makers/stakeholders face with weighing collective/private benefits that impose risks on public, this would create an inequitable situation.

However, regardless of the different stakeholders with different standpoints, there always should be a prioritisation, particularly in large social technical system, which is associated with public general welfare. Apart from fulfilling each of the stakeholders' interests, the ultimate objective in any economic welfare project economic like biofuels introduction is to safeguard the general public interests on social, economic and environmental benefits. Any self-inferential conflicts, should give way to the public interest. Arguably, either at one extreme, a decision has to benefit “every member” of the society to be truly in the public interest; or at the other extreme, as long as it benefits the population at large. The bottom line is, at least full rational considerations have to be made for those who are vulnerable and those are living in poverty. Biofuels should not cause the expensive food prices that affected the poor and led them to hunger. Equally, biofuels should not destroy the ecology, where vulnerable flora and fauna living as their home.

7.4 Social Shaping the Next Generation Biofuels

Although biofuels are operating under the regulated market, this setting is not a close/isolated context. Apart from the regulators/oil companies involvements, their decisions made on biofuels deployment is also being monitored by the international/local pressure groups. After the emergence of two systemic risks, the representation of the local pressure groups in the British public was growing gradually and being strengthened significantly. There was a substantial institutional and power shift (as discussed in 7.3.2), with a new demand to pressurise the UK Government on the G&S criteria enforcement of the biofuels product, production and supply in the domestic market.

The UK Government and the oil companies learned that, if the G&S criteria had not been instituted and enforced, the objections from these pressure groups/media would be endless. Besides, the public pressure which had been projected through broadcasting/print media and the pressure groups' campaigns had been forceful and vocal. If the government was perceived not taken any action within a reasonable time, then the public's anxiety may have been heightened. A sense of crisis could have developed and would have taken on its own momentum, which could have resulted in the termination of biofuels adoption. This would have a seriously negative consequence for the government, and the oil companies who have invested heavily in the NGB development. From the viewpoint of public order and corporate social responsibility, the government and the oil companies would hope that their rapid response would allay the public tension in order to protect their reputations.

Consequently, the assessment of biofuels deployment has changed. The regulatory concentration which initially focused at achieving various mandatory targets has been slowed down, to allow biofuels implementation to continue under a set of newly altered RTFO targets. Stringent G&S criteria on biofuels are legally enforced, through higher transparency of biofuels data requirements (guided by the Meta/Qualifying standards) which are reported monthly by the oil companies/biofuels suppliers to the RFA. The G&S message gradually appeared across regional/national for the updated/altered policies. The RFA has set stringent G&S criteria as one of the requirements to award its RTF certificate to the qualified biofuels suppliers who can prove that their biofuels are G&S in products, production and supply. Subsequently, a new trend is shaped, which kept emphasising at the G&S criteria on biofuels product, production activities along the value chain and supply. These new inputs have also constructed a new landscape for the existing biofuels deployment and the NGB development.

Reflecting on the UK Government's decision to alter the RTFO targets in 2008, it was merely a “treatment” for the two systemic risks, to slow down biofuels expansion, and to enforce the biofuels supplied under a stricter regulatory control. However, this treatment still cannot ensure that these two systemic risks will not arise again. As long as the food-derived-1G biofuels is still in use, there is still a possibility of food-fuel tension and biodiversity damaged to reoccurred. Therefore, a better technology (the NGB) with robust G&S criteria is needed.

The NGB technology once developed, not only could shift biofuels away entirely from the food chain, but also could be grown on idle land/sea. These benefits have provided some positive solutions to prevent the reoccurrence of systemic risks. Besides, there is a prospect of achieving a long-term sustainability from the NGB, which would allow the fulfilment of the respective motivations[258] of both the regulators and the oil companies.

7.4.1 Social Shaping Nine Criteria/Requirements for the Next Generation Biofuels

This research points out, to date, the NGB has nine criteria/requirements-that have been contributed by the respective stakeholders, that involve the mixture of public, private and semi-public organisations as shown in Table 7.4.1 and Model 2.

Table 7.4.1: Nine Criteria/Requirements of the NGB

Criteria/Requirements of the NGB	Required by
1. Consistent supply to fulfil regional/national mandatory targets 2. Non-food	Regional/national regulators
3. Environmentally green for social and environmental benefits 4. Lower carbon footprint (activities along biofuels production and supply chain)	Pressure groups, environmentalists, social movements, biofuels roundtables and regulators; all emphasis the G&S requirements on biofuels product, production and supply
5. Higher yields	
6. High efficiency of conversion process	
7. Higher performance: better fuel efficiency, greater engine performance	Oil companies
8. Lower production costs 9. Quicker tangible results	

Source: Summarised by the researcher

According to Rip and Schot (2002), innovation starts with the identification of a technological opportunity, a new option/solution for an existing problem. Such options may derive from R&D findings which justifies why the NGB is under development. Since innovation is an uncertain process, it is not just a rational-technical problem-solving process; but it also involves social, economic and political

258 explained under the three respective driving forces at 7.1.1 and 7.1.2.

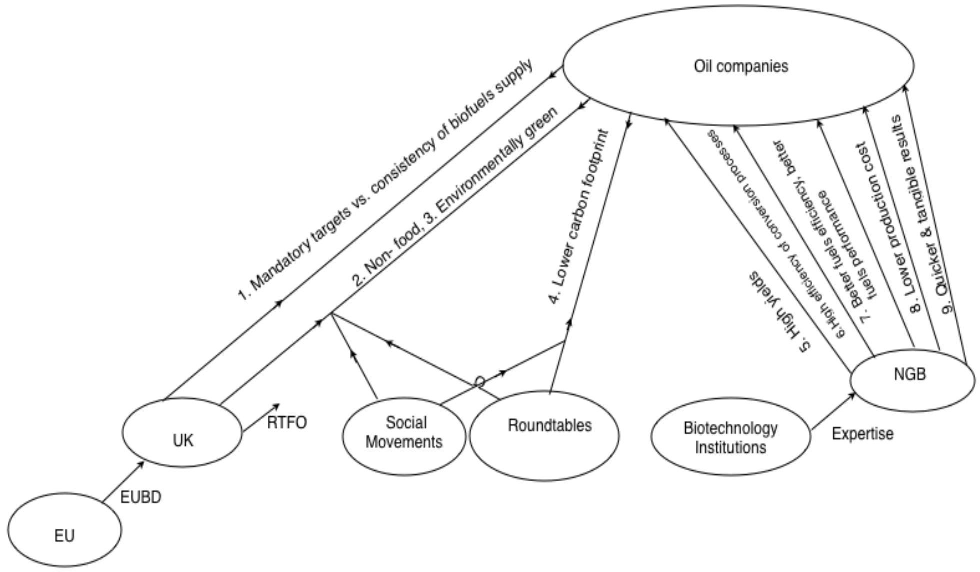
processes in building alliances of interests amongst all stakeholders; with the resources and technical expertise around certain concepts/visions, and as an unrealised technology for the point of future application (Williams and Edge, 1996) (refer literature 2.2.4).

These nine criteria/requirements seem have provided a set of clearer and a more certaint yardstick for the NGB development. They have a few objectives: Firstly, solving the limitations/weaknesses of the 1G biofuels. Secondly, adopting new inputs which were learned from the emergence of two systemic risks. Thirdly, respective interests on respective stakeholders[259] are found. These social actors are influencing the content of the NGB technology and its social implications. Meanwhile the development process involves the collaboration among these stakeholders through inter-organisational interaction which is patterned by various social factors: political, social, institutional, economic and environmental.

During the process to develop these nine criteria/requirements, different types of mechanisms (encouragement[260], control[261] and preventive[262]) are used by the stakeholders involved, in order to affect the final decision, so that it matches their own perceived interests. The democratisation of these decisions is to combine the external interests-socioeconomic benefits, and the respective internal interests by reflecting the self referential aspects.

259 The regional/national governments' political interest to achieve mandatory targets; the pressure groups, biofuels roundtables, environmentalists and social movement agenda to safeguard the socioenvironmental benefits, and the oil companies' motivation for the economies of scale.
260 In April 2010, the UK Government started rewarding biofuels (through incentives) supplied under the RTFO based on the amount of carbon the fuel saves. This will be subject to compatibility with the EU and the WTO requirements. Then April 2011, the government rewards (through incentives) biofuels which they meet all the sustainability standards outlined by the RFA and respective roundtables (RTFO, 2008).
261 Regional/national mandatory targets as one of the measurements, to control biofuels implementation.
262 Non-food biofuels and G&S biofuels product/production. G&S criteria have been specified in the rules and regulations under the RFA, controlled by the RTF certificate, after being deemed as one of the core criteria at respective roundtables. This is to prevent the reoccurrence of two systemic risks that arose in 2008.

7.4.2 Nine Criteria/Requirements for the Next Generation Biofuels Development



Model 2: Social Shaping Nine Criteria/Requirements for the NGB Development

Source: Summarised by the researcher

(1) The regional/national biofuels demands will follow an exponential growth for many years to come, as guided by the EUBD (2003) and the RTFO (2008) mandatory targets. Since the EURED (2009) requires 10% of energy used in transport to be renewable by 2020, this target would also count in biofuels as one of the RE profiles for transport use. Therefore, consistency of biofuels supply is vital, in order to ensure that these political mandates will be achieved within the defined period.

(2) Since the 1G biofuels is largely derived from food, the food-fuel competition has caused food prices increased dramatically. To avoid this from reoccurring, the NGB feedstocks have to be switch entirely away from the food chain. Therefore, the NGB

feedstocks could be sourced from industrial/household wastes[263] and non-food vegetations[264].

(3) To stop the ecological deterioration and invasion on food farms, the NGB feedstocks farming must be able to safeguard the socioenvironmental benefits and minimise the negative impacts on land and water use. These include:

i. Feedstocks which require minimum/no agrochemicals/fertilisers use to minimise land pollution.

ii. Feedstocks which do not grown/produced from high biodiversity areas (jungles, forests, wetlands and preserved areas).

iii. Feedstocks which do not create land competition between farms and biofuels plantations

iv. Feedstocks which have lower water footprint, do not put added pressure on fresh water use and could be grown under natural irrigation.

v. Plantation/production plant which do not employ forced labours or child labours.

These criteria have been established by all the biofuels roundtables[265] (refer Appendix 7.4.1). The roundtables' P&C are acting as the control/preventive mechanisms, in order to ensure biofuels supplied are G&S. The P&C correlate to front-line people such as farmers, producers, traders do on the ground through the activities of growing feedstocks, manufacturing biofuels and trading.

(4) The lower carbon footprint of biofuels is emphasised by four roundtables, on the ground of good agricultural practice[266]. According to respective roundtables, it is scientifically proven if a good agricultural practice (energy saving and environmental

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263 used cooking oil, animal tallow and agricultural/forest residues.

264 energy grasses (miscanthus, switchgrass), non-food oil seeds (jatropha) and also algae.

265 Up to date, there are four biofuels roundtables: Roundtable for Sustainable Biofuels (RSB), Roundtable on Sustainable Palm Oil (RSPO), the Roundtable for Responsible Soy (RTRS) and the Better Sugarcane Initiative (BSI).

266 minimising energy input on production activities; low fertiliser/agro-chemical use; low water footprint; no high biodiversity lands are converted for biofuels plantations; and choosing feedstocks which portray a sustainable criteria for low energy demand.

responsible) are implemented, the activities along the biofuels value chain[267] could result in low-carbon emission. This is because, each activity requires energy. The amount of energy input determines the amount of carbon emission.

However, there is not universally true for all biofuels types, and carbon reduction from biofuels may vary depends on the feedstocks grown. Some feedstocks could produce a higher yield naturally which portray the sustainable[268] criteria, while others would require a higher energy input (fertiliser, agrochemical). Therefore, highly energy efficient fuel crops, well-planned land use and well-managed activities are playing their part in the biofuels carbon equation. If the activities can be managed well by employing the good agriculture practice and integrate to minimise the CO_2 release, these sum up would have a significant G&S biofuels products, production and supply.

(5) Some of the feedstocks can produce a higher yield naturally. Yet, the natural capability is also affected by geographical factors such as: climate/weather, soil types, nutrients and water supply. One of the aims for the NGB R&D is to seek for higher yield feedstocks that can produce more biodiesel/bioalcohol[269], yet at a lower cost (refer appendix 7.4.3).

(6) The existing processes used for bioethanol (fermentation) and biodiesel (transesterification) production are extended from the conventional technologies used for wine/beer production and the synthesis of polyester respectively. The major weaknesses of these two processes: they are time consuming, suitable for small/medium scale production, and can only deal with simple inputs like

267 The activities begin from seeding, fertilising, irrigating, growing the feedstocks, harvesting, transporting to the production plant, manufacturing into biofuels, transporting for trades and finally supplying through the distribution system.
268 Sustainable feedstock, according to BP's definition is a feedstock that is produced in a way that conserves an ecological balance by avoiding depletion of natural resources (BP, 2006a). Refer appendix 7.4.2. For example Brazilian sugarcane has 90% of carbon saving from farm-to-wheel, when compares with petrol from well-to-wheel basis. It requires no fertiliser, less transportation where the processing plant is located near to the plantation, and the production plant reuses the by product (bagasse) to power the production (Worldwatch, 2008).
269 with the unit of feedstock measurement in “litre per hectare” (L/ha).

starch/sugar or fat.

Since the NGB cannot be extracted from the food chain, the input for bioethanol must not be from fruit (corn), instead the other parts of a crop (stem or leaves). The complex sugar found from the stem/leaves (lignocellulosic) requires a greater efficiency of conversion process, which has challenged the existing fermentation and transesterification technologies. Hence, the applications of super enzymes, new catalyst and a cutting edge production technology capable of producing higher quantities of biofuels (from lignocellulosic)[270] are required.

(7) Better fuel efficiency and greater fuel performance are the objectives to enhance the current performances of the 1G biofuels, by solving its limitations/weaknesses through the NGB R&D. First, there are three weaknesses[271] on bioethanol (refer appendix 7.1.2a) which have captured the oil companies' attentions. Through R&D[272], BP and Shell aim to breakthrough these limitations. Next, for biodiesel, one major problem is its strong solvent properties on the existing ICEs' (refer appendix 7.1.2b). To date, BP[273] and Shell[274] each has two NGB R&D projects that aim to break through the solvent properties.

(8) Economies of scale would be achieved if biofuels could be produced in a larger quantity with a lower cost. This could be achieved after taking into consideration of maximising the biofuels outputs and minimising costs/energy/inputs for each of the activities involved along the biofuels value chain.

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270 The current examples are: wheat straw to bioethanol (Shell-Iogen), biomass to liquid (Shell-Choren), sugar to biogasoline (Shell-Virent), photosynthesis bacterium to produce biodiesel (BP-Arizona State University) and sugar to biodiesel (BP-Martek).

271 Low heating values, low energy content-bioethanol accounts only 2/3 of gasoline energy content, and high water affinity.

272 BP JV with DuPont researching on biobutanol, while Shell joint R&D with Virent to convert sugar to biogasoline- which has some similarities of petrol. Both biobutanol and biogasoline will demonstrate better performance than existing bioethanol, with higher energy content, higher heating values and lower water affinity.

273 BP funds Arizona State University to conduct bacterium produced biodiesel. BP joint development with Martek to convert sugar into biodiesel.

274 Shell JV with Choren for biomass to liquid (BTL) conversion into biodiesel. Shell JV with HR Biopetroleum for the 3G algae towards biodiesel production.

The identification (through R&D) of naturally high yield crops which can be grown in areas of low economic activities (idle/marginal land), would contribute to a higher quantity of biofuels produced, yet, with lower costs of land/resources use. Crops like miscanthus and switchgrass[275], sugarcane[276], jatropha[277] and algae[278], are not only in high-yield naturally, but also require low energy for growing. They do not require additional fertilising and they have low water footprint.

If a plant is located nearer to the plantation, the transportation costs would be reduced. Besides, like Brazilian sugarcane, if by-product (like bagasse) is used to power the production process, this could help to cut down the energy cost significantly. Furthermore, the research on super enzymes, new catalysts and cutting edge production technology, are contributing to speed up the manufacturing process and to produce biofuels cost effectively.

What we can observe from this, although while some of the activities are largely dependent upon a good agricultural practice and machineries application (for seeding, harvesting, and transportation); some activities could be boosted by new technology developed through R&D, which can contribute to higher economies of scale.

(9) Since the NGB technology is anticipated to be commercially available five-to-ten years from 2008, the biofuels market is awaiting a pioneering breakthrough from one of the leading oil companies to produce the tangible and reliable NGB results in the fastest time. The pioneer status is important for any oil companies operating within an oligopolistic market structure; as this status would subsequently secure a lucrative long-term business prospect, helping the oil company to conquer the untapped biofuels market as soon as possible.

275 Perennial grasses require low fertiliser and agrochemical, and can be grown on set-aside land.
276 In Brazil, the sugarcane residue (bagasse), is used to generate heat and electricity to power the production plant, thereby making the manufacturing process more cost effective and more environmentally friendly (Knott, 2007; BP, 2007a).
277 jatropha is drought resistant, which can be grown on marginal land.
278 algae is cultivated through sea-farming, which would not put added pressure on land/water use.

7.4.3 Basic Features of Nine Criteria/Requirements for the Next Generation Biofuels

There are three basic features of these nine criteria/requirements. Firstly, they are fabricated through the determinate process of technological design, expectations and lessons learnt from the 1G biofuels trials/explorations. We could see them as the collective decisions, resulting from the interactions among the various stakeholders, rather than as a single cell decision.

These nine criteria/requirements have been portrayed as the prerequisites for the NGB development. They converge each of the stakeholders' interests[279] which have been incorporated to achieve the goal of getting the NGB technology to work in a useful/practical way for future application. They are the guidelines for biofuels the industrial players and the policy makers. This has shifted the existing concentration from being solely to achieve targets (quantity driven) as the ultimate objective, to a more G&S biofuels as the new parameters (quality oriented) to measure and control biofuels products, production and supply. Currently, these nine criteria/requirements are being simplified to keep the overall picture manageable, and being classified to characterise activities: science/technology, market/society, environmental/economic and regulation. As a result, each of them works harmoniously in terms of intermediaries and interactions by various stakeholders.

Next, these nine criteria/requirements are entities that have some degree of continuity over time. They do not appear as completely static or to be set in stone. This then complies with the nature of technological innovation, which is dynamic, evolving; and there are always debates about the direction of the NGB technology during its development. We would expect some continual reassessment from the 1G biofuels deployment, which the feedbacks will contribute to the expansion and more the G&S criteria to be fitted in the NGB development. If this situation takes place, we would anticipate some sudden climacterics changes, as well as incremental adjustments and steady trend. The dynamism and evolution will be due to either some minor

279 needs, requirements, interests, values, goals, targets and guidelines.

adjustment in one of the nine criteria content, or will be an extra item/new input to be added which caused a step-change in the context. The rule of thumb is, technology, once developed and implemented, not only will react back upon their environments, but will also generate new implications (Clark and Staunton,1989; Fleck, 1993) (refer literature 2.2.3.1). Therefore, it is important to enrich the innovation journey, by anticipations and social feedback. As Rip and Schot (2002) suggest, the anticipations of outcomes, including impacts of the technology on society must be an ongoing concern, rather than ad-hoc efforts to persuade the stakeholders within the dynamics of such developments in context (refer literature 2.2.4). The learning made possible through scenarios, is especially important for any development stages of the NGB.

Thirdly, these nine criteria/requirements are seen as relatively bounded context that can be specified at different levels of breadth. While it could be described from an international perspective for the biofuels cross-borders trades; we can also conceive the context in a narrower sense as the system of control that centres at national/local level. This is particularly important for biofuels farming/exporting countries, in order to safeguard the local socioenvironmental impacts and maintaining the G&S criteria by "thinking globally and acting locally".

7.5 The Scottish Government and the Oil Companies in the Next Generation Biofuels Development

Compared with the UK Government, the SG demonstrates a more progressive effort in the NGB development under the Devolved Matters. It has established some pioneering works, like the UK first biodiesel plant and the UK first biofuels research centre. There are other ongoing R&D projects to foster the NGB development in Scotland.

The SG's work has been discussed in section 4.2.2. There are obvious different affinities (reflected from the respective policies), where the UK Government favours H_2/electricity as the REfT, while the SG prefers biofuels. Meanwhile, both BP and

Shell have a large transport fuels market share in the UK. BP has more than 1300 kiosks (BP, 2010d) and Shell has more than 900 kiosks (Shell, 23 November 2009). Besides, BP and Shell are two of the world's six oil companies which are currently embarking on the NGB research (refer appendix 7.1.1). Their progressive effort into the NGB R&D since 2003 and 2002 respectively, demonstrates their early involvement in the NGB development in building up their pioneer status.

Looking at the nine criteria/requirements (discussed in section 7.4.1), there are three motivations for the SG and the oil companies to pursue the G&S NGB development. Firstly, the regional/national political mandates are demanding a consistent biofuels supply, in order to ensure these mandatory targets could be achieved. The NGB, which could be produced in larger/consistent quantities, would support the execution of these regional/national targets.

Secondly, the economic interests of the SG in creating national wealth, through green economy activities and the profit making objective of BP and Shell. Their venture into the NGB development also builds up the national/corporate core competency by pioneering the untapped NGB global/domestic market. As such, the economies of scale of the NGB could be achieved by new feedstocks and novel process technologies.

Thirdly, based on the EU/UK regulatory requirements, and pressure from the international/local pressure groups, the NGB must be switched away entirely from the food chain and be G&S. After the emergence of two systemic risks, the international/domestic community realised the importance of the G&S biofuels adoption. Therefore, the general public subsequently demanded the corporate social responsibility, as well as the accountability of public governance in protecting socioenvironmental benefits. Furthermore the P&C advocated by respective roundtables are promoting good agricultural practices, in order to ensure that every activity along biofuels value chain is properly managed and to achieve a lower carbon footprint. The NGB would be sourced from sustainable non-food crops, grown on marginal lands and require a lower energy input all of these could safeguard the international/national socioenvironmental objectives.

7.5.1 Expected Risk and Uncertainty Faced by Governments and Oil Companies during the Next Generation Biofuels Development

Since the expected R&U have multitude dimensions, the divisions of R&U which are faced by the regulators and the oil companies, could separate the overlapping of R&U and contextualise them accordingly. The nine criteria/requirements of the NGB, and mechanisms put in place (discussed at 7.4.1), not only helped to deliver the anticipated results of the NGB, but they were also characterised by the risk preventive objectives, to mitigate the expected R&U for the ease of the NGB deployment.

Elliott (2003d) advocates a set of expected R&U from the regulators'[280] perspective on RE development, along with the strategies applied (as summarised in table 2.3.1 and 2.3.2). Besides, there are three[281] expected R&U from the corporate perspective on technology development, advocated by Rosenbloom and Kantrow (1982), Pearson (1991), Rosenberg (1994) and the SpecialChem (2011) report with the counteracting strategies (as summarised in table 2.4.1). This research utilised these frameworks to analyse the NGB development, and summarised the findings in Table 7.5.1 and 7.5.2.

280 [1]Political support, [2]funding, [3]social acceptance, [4]technology, [5]institutional interests and involvements.
281 [1]Technology, [2]business operations and [3]social acceptance.

Table 7.5.1: Risk and Uncertainty and Strategies Applied by Regulator during the NGB Development

Types of R&U	Findings	Strategies adopted
Political supports: 1. Rhetoric, lack of vision.	1. The SG has a strong vision of the NGB development, backed by the regional/national biofuels policies.	1. Strong political support from the EUBD (2003), the UK RTFO (2008) and the EURED (2009), are helping biofuels to claim a larger share as one of the profiles under the REfT. The SG has formulated the Renewable Action Plan (2009), taking in the NGB as one of the focuses for the RE development. These policies are building biofuels into a long-term business prospect, which ensured a high confidence level of various private sectors on their respective investments (oil companies, biotechnology institutions, agricultural industry, biofuels producers/traders/suppliers). The SG showed its progressive efforts in the NGB development. Evidenced by tangible results: Construction of Argent Energy Plant (the first in the UK); establishment of a Biofuels Research Centre at Napier University (the first in the UK); and a Biomara project (algae biofuels) at Oban is ongoing.
Funding: 1. Inadequate/ sudden budget slash from the government.	1. Inevitably, the NGB R&D projects are time consuming and require enormous capital and resources. However, the NGB R&D projects are running independently, funded by the SG and the oil companies separately.	1. The ongoing NGB R&D projects are working in parallel, but are separately funded by two different investors: the regulators and the private sector. Hence, there is no reliance by the private sector on government fund as the previous RE projects did-and as a result which were mostly failed in the UK. At the political level, the combined financial strength from the EU/UK/SG funding resulted in the completion of Argent plant and supporting the ongoing Biomara project in Oban. Meanwhile, BP and Shell have pooled the resources from their partners, to conduct the NGB R&D projects.
Social acceptance: 1. Right time? right technology? right place?	1. Right time and right scenario on combating climate change, green economy evolution and to avoid the occurrence of systemic risks.	1. Biofuels development is set at the right time with right political, social, economic and environmental climate. The contemporary international attention is to avoid the occurrence of the two systemic risks by stressing the G&S of biofuels; to combat climate change through road transport GHG/CO_2 reduction; and to achieve energy security. Mean while some countries are working intensively to switch centuries of petroleum-dominated-economy to a green economy.

2. Disinformation resulting in the low appreciation of the NGB technology.	2. Accurate information from the reliable organisational media, websites and reports.	2. The G&S criteria of the NGB are promoted through governments', oil companies' and independent institutions' organisational media. The political message “prioritisation on the G&S biofuels” appeared mostly across regional/national biofuels policies. Besides, the benefits of the NGB to counter-solving the limitations of the 1G biofuels (derived from food, threatening biodiversity) are published by oil companies/independent institutions to regain public confidence on the NGB.
The NGB Technology-Between performances and expectations 1. Not understand the technical criteria of one technology. 2. Unrealistic high expectations upon the NGB technical performance. 3. Asking too much too soon from an embryo technology.	1. The NGB finished products are still categorised under biodiesel or bioalcohol. 2. Realistic expectation on the NGB technology. 3. Guided by the RTFO for a set of bottom-up target fulfilment.	1. The NGB once successfully produced will still be categorised under the organic biodiesel and bioalcohol. They are not a completely new product; yet, they might appear in a more complex chemical structure, which would overcome the limitations of the 1G biofuels. This is because, for the near-term application, biofuels still need to be blended with petrol/diesel. The NGB is expected to have resolved the weaknesses of the 1G biofuels, to foster the market acceptance. 2. The main function of biofuels use in the UK is to reduce road transport GHG/CO_2 emissions. The NGB technology has to continue to perform this role, or even be better. Besides, the NGB should have the G&S criteria that could protect the socioenvironmental benefits, and would not recreate two systemic risks that occurred during the 1G biofuels deployment. However, the NGB could not be taken as the sole REfT, and expect it to substitute petrol/diesel. This is because, no single RE has the capacity of oil/gas to be substituted. A diversified REfT profile such as H_2, electricity would help by complementing one and another, to fulfil the future energy demands, and also provide more choices for consumer on different types of green cars (biofuels/flex-fuel/H_2/electric cars). 3. The NGB technology has not been pushed too far at the early stage. The time gap of five-to-ten years from 2008 was set, which supported by the EURED-by 2020, 10% of the transport fuels have to be sourced from the RE. Besides, the altered RTFO, demands 5% of biofuels to be applied by 2013/2014. This would allow for a gradual process of new technology innovation: from the NGB R&D,

		innovation to solve the limitations of the existing 1G biofuels then moves to the full scale commercialisation. The bottom-up approach (gradually increasing biofuels targets) can ensure the NGB R&D projects are guided, allowing for piecemeal adaptation in order to obtain feedback and learn from the mistakes made during the 1G biofuels implementation.
Institutional interests: 1. Institutional biases/structure resistance which resisted the development of the NGB technology: 2. Lack of commitment from industry.	1. Converged political interests at different levels: EU/UK and the SG. 2. Profit driven oil companies are eyeing on biofuels market.	1. Due to the regional/national biofuels adoption is a political mandate, no evidence was found on the confrontation of biofuels between EU/UK/Scottish Government. There are a few biofuels development projects which obtained funding from the EU/UK Government that demonstrates their political interest and support. 2. Biofuels is guided by the political aims and would be sustained for long-term application. Hence, the oil companies are eyeing on biofuels, as one of the most lucrative business opportunity which could sustain their energy businesses.

Source: Summarised by the researcher

Table 7.5.2: Risk and Uncertainty and Strategies Applied by Oil Companies during the NGB Development

<table>
<tr><td rowspan="2">Types of R&U</td><td colspan="2">Strategies adopted</td></tr>
<tr><td>BP Approaches</td><td>Shell Approaches</td></tr>
<tr><td>Technology
i. Uncertainty about ends</td><td colspan="2">The NGB R&D projects conducted by BP and Shell are working to match as closely as possible to the nine criteria/requirements laid out. These nine criteria/requirements seem to provide a set of clearer and more certain yardstick for the NGB development. They correlate to each of the stakeholders' needs, interests, values, goals, targets-which have been incorporated in order to get the NGB technology to work in useful/practical ways, at the point for future application (refer 7.4.2).</td></tr>
<tr><td>Innovation processes
i. Beyond oil companies institutional knowledge in the NGB development</td><td>i. Resolves the limitation of institutional knowledge in the NGB development
-R&D collaborations with external biotechnology institutions and agricultural.
-owns in-house R&D institution-EBI which is carrying various the NGB research.</td><td>i. Resolves the limitation of institutional knowledge in the NGB development through:
-R&D collaborations with external biotechnology institutions.</td></tr>
<tr><td rowspan="2">ii. Beyond oil companies institutional capabilities in the NGB production</td><td>ii. Resolves the limitation of institutional capability in the NGB production, JV partnerships were established to set up a production infrastructure.
-with British Sugar and DuPont for biobutanol plant.
-with Tropical for Sugarcane plant.</td><td>ii. Resolves the limitation of institutional capability in the NGB production, JV partnerships were established to set up a production infrastructure.
-with Iogen for wheat straw bioethanol demonstration plant.
-with Choren, Biomass to Liquid demonstration plant
-one pilot demonstration plant with HR Biopetroleum (algae).
-with Cosan for sugarcane processing facilities.</td></tr>
<tr><td colspan="2">Generally, risk transfer strategy is applied from the oil companies. They are transferring the risks/inadequacy of knowledge and production capacity of the NGB to the research institutions</td></tr>
<tr><td>Social/market acceptance on the NGB
i. the ripple effects of two systemic risks.</td><td>i. Promotes the G&S criteria of the NGB technology (which are non-food, has low-carbon footprint and does not create land competition).</td><td>i. Promotes the G&S criteria of the NGB technology (which are non-food, has low-carbon footprint and does not create land competition). Besides, a webchat session was broadcasted to answer the 1G biofuels controversy.</td></tr>
</table>

ii. The public does not know about the NGB technology.	ii. Educates the public on the latest information about the NGB technology. -i and ii activities are generally conducted through organisational website, corporate online videos and published reports.	ii. Educates the public on the latest information about the NGB technology. Meanwhile Shell is also building social/market acceptance on the NGB technology with two strategies: (a) one month market test run in Ottawa on the wheat straw bioethanol. (b) working with Ferrari and Ducati in racing competitions, to test the NGB performance. -i and ii activities are generally conducted through organisational website, corporate online videos, YouTube, and published reports.

Source: Summarised by the researcher

According to the oil companies' representatives, since the 1G biofuels is just a start, it has provided a platform for the long-term NGB business prospect. The potential of biofuels could be explained through the NGB by stressing the high-yield/non-food feedstocks (biomass[282]/waste[283]) and the efficiency of the process technology. By applying bioscience/biotechnology to the NGB product and production, various ongoing R&D projects will put BP and Shell at the fore front in speeding up their market penetration and enhance the economies of scale through the NGB outcomes.

7.5.2 Empirical Suggestion for the Oil Companies' Diversified Strategies for Biofuels Development

Both BP and Shell are continuing the supply of the 1G biofuels while carrying out the NGB R&D. To date, these companies have similar strategies embarking on the NGB R&D. in order to ensure that they will gain the greatest potential for profitable growth from the NGB technology. Therefore, all collaborative R&D projects are established between BP and Shell with their respective cross-border biotechnology

282 There are generally three types of biomass source: firstly the natural forest residues; secondly, the left over biomass/by products (whole plants after fruits have been harvested, like wheat straw, sugarcane bagasse and corn kernel); and thirdly, purposeful energy grasses, such as miscanthus and switchgrass.
283 animal fat, used cooking oil and industrial/commercial/households wastes.

institutions/agricultural partners. This is because, BP and Shell do not have adequate institutional knowledge in developing biofuels from the biotechnology sphere. Besides, they do not have the capability to produce their own biofuels. Both inadequacies are the main risks that these oil companies are facing.

Advocated by Dorfman (1997) (refer literature 2.4.3), risk transference is the strategy that both BP and Shell are using. They allow other parties (research institutions and agricultural players) to bear the risk on behalf. This strategy enables the oil companies to shift into higher gear to concentrate on one of their competencies (expanding the energy market share and the NGB marketing), while allow the NGB R&D projects to be transformed underway. These research institutions and agricultural partners have the absolute advantage of expertise and profound biotechnology knowledge. They help BP and Shell to materialise the NGB technology required. Consequently the structure between the oil companies and these R&D institutions has changed. Through the collaboration for biofuels development, both are now strongly connected by the economic motivations of profit making and wealth creation.

The different modes of collaboration are aimed at the NGB commercialisation. In the end, BP and Shell can utilise their research findings as assets for profit making. These collaborations could result in two implications: Firstly, the knowledge transfer from the external laboratories/agricultural players to BP and Shell, enables them gradually build up their institutional knowledge associated with biotechnology for biofuels innovation and production.

Secondly, these research institutions/agricultural industry could have the opportunity for profit seeking with BP and Shell. The research outcomes could be patented for commercial purposes, and this would lead to a lucrative profit sharing between BP, Shell and their biotechnology/agricultural partners. To date, BP has ten, while Shell has seven NGB development projects ongoing, which utilises three modes of collaboration: equity joint venture (JV), strategic alliance (SA), and direct funding.

All of these modes are aimed to transfer the R&U to the “experts” whom are suitable and capable to deal with them, mitigate the risk exposure and to pool the resources required from their respective partners to achieve wealth creation for both parties (refer appendix 7.5.1).

7.5.3 Empirical Suggestion for Diversified Strategies Associate with Different Technological Confidence Levels

Apart from costs sharing, the R&U and the resources sharing for the NGB development process, different strategies for the various modes of collaboration adopted by the oil companies could also signify the different levels of technological confidence for the oil companies in the particular NGB projects. By using Pearson Uncertainty Map (PUM) on different quadrants (Qs) (refer literature 2.4.2), this research suggests an extended interpretation on the PUM, correlates it with different technological confidence levels.

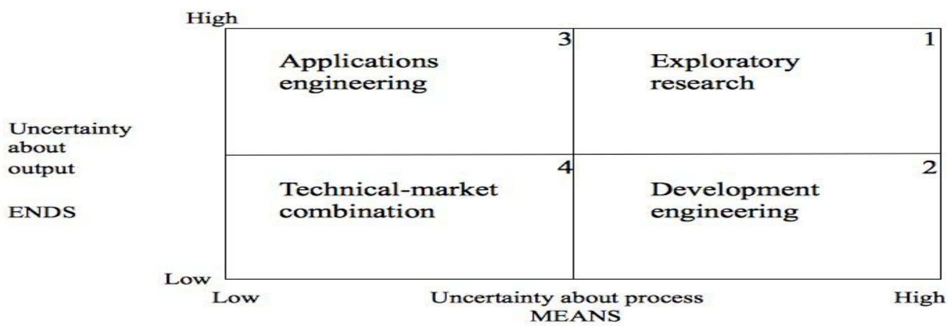

Figure 7.5.1: Pearson Uncertainty Map

Source: Pearson (1991).

If one technology is applicable and promising, it would provide a higher confidence to the stakeholders. Therefore, the partnership would be strengthened through JVs. Hence the JVs projects agreed so far, are specified with defined technologies, whereby the results are clear but the processes are yet to be established. These criteria are fall into the Q2. Pearson (1991) explains, projects in Q2 require advanced technology, and the transition to manufacturing is complex. Besides they need large-scale of resource to be committed and high rewards/motivations in order to push the efforts in pursuing the development. This justifies the JVs taken place between the oil companies and the biotechnology institutions/agricultural industry, which show a large portion of their contributed resources, since they are confident on the lucrative returns.

Meanwhile, SAs allow the combination of both parties know-how to innovate products of the NGB. The technological confidence level is moderate. This is because, the driving force is based on the assumption that, a process technology is known and has the potential to generate a new product. However, neither of the parties has certainty about the success of the research outcomes[284]. These criteria fall into the Q3.

Since a potential/new NGB product might be produced by a known process, SAs enable the product to be developed within a defined period of time and under controlled resources, in order to avoid being trapped in a black hole effect[285]. Meanwhile, each partner remains independent without pulling their parent company into this collaboration. Therefore SAs permit cooperation to be specifically tailored for both the researcher's capability and the oil companies' requirements, thereby bridging the scientific ability to the commercial possibilities.

Finally, funded projects have two distinctive confidence levels of technology. For simple technology which gives a high confidence level, the project fall within the Q4. For example, the BP-TERI jatropha project. Since the operations in plantations are general (seeding, growing and harvesting the jatropha), they do not require BP's continual involvement in the daily activities on site. Instead, BP entrusts the capability of TERI (controlled by the agreement) to have this project run efficiently and effectively. Therefore, this demonstrates that BP has a higher confident in the technology and allows its partner run the project.

284 Questions to be considered: Would it be successfully developed within an acceptable period of time? Will the outcomes be usefully deployed for commercial purposes?
285 requires unlimited financial injections which would jeopardise the entire company and result in the possibility of bankruptcy.

On the other hand, funded projects also fall in the Q1, which demonstrate a low technological confidence of the stakeholders. The Q1 activities often involve working with product and process technology that is not fully understood [286]. According to Pearson (1991), this is largely the domain of university research laboratories. Increasingly, the oil companies have the necessary resources to fund such exploratory studies. It is suggested that Q1 might best be left to the scientists. BP and Shell funding projects are fall into Q1. These projects show that, there is a significant insufficient knowledge about the product/production technology, which necessitates the need for the basic/applied research. What BP and Shell want from the collective of funded research projects, are to investigate new feedstocks and novel production processes, to focus on the technology options that give a feasible set of commercial solutions.

For example, BP is funding the Arizona State University while Shell is funding six universities research projects. Geographically, Arizona has rich natural resources for forest, desert and park land. Meanwhile, Shell-six universities projects are spreading across four continents: US, Brazil, China[287] and the UK. These research projects have one thing in common: these projects, not only based on each universities' expertises, but also the different locations could have the potential new feedstocks found.

To conclude, the PUM helps to understand uncertainties about means (process) and ends (output). The arrangement of the quadrants with the types of research addresses precisely the solution needed under the contextual constraint of these two uncertainties. Furthermore, it could be used to reflect the different technological confidence levels, which could determine stakeholders' diversified strategies to opt either for JV, SA or direct funding. Although PUM's characteristics have been briefly

286 We know the nine criteria/requirements of the NGB, but we do not know which types of feedstock are the most efficient (as every vegetation has its own unique yield capacity), where to find these feedstocks (geographical habitat), and how to have these feedstocks largely produced.
287 Two locations in China: Beijing which is the capital of China and Qingdao which is located on the coast line, which could provide a potential feedstock according to the location advantage.

described, its real value lies in its ability to help identify important characteristics, which if taken into account will reduce the R&U of innovation/technology development. It could be of great help since it focuses on the nature of the R&U and raises issues of technology, organisational structure, interests, capabilities and strategy.

7.5.4 Empirical Suggestions for the Unresolved Risk and Uncertainty

(a) Cross-Border Plantations

BP and Shell large-scale sugarcane plantations and BP's jatropha plantations, would initially assume that, most of the anticipated R&U have been resolved. For example site investigations have been conducted to identify the most suitable location for the plantation, in order to overcome the nature restraints. The operations would be equipped with adequate facilities by pooling their partners' resources of capital, infrastructure and manpower. Even though with the most prepared strategies in place, there are still many unanticipated factors which might render to the emergence of R&U. For example the unpredictable weather which could cause a low harvest.

Furthermore, growing feedstocks in a cross-border project with a large-scale plantation for a long-term period could cause the project to be exposed to a number of challenges. This includes political influence from the host country[288], real economic impacts on local communities[289] and social reaction[290] would generate some unexpected R&U.

288 Host government changes through a general election could invite new regulatory obstructions. There is no guarantee the new government would continue to support the large-scale plantation. There is also a risk when the host government acquires land under its new community development.

289 Some socioeconomic concerns could be helpful for reflection: Is there any equal employment opportunity provided to the community? Are these employment opportunities long-term or short-term? How to solve problem if child/forced labour is detected in the plantation? What need to be done if various unions have been set up to demand higher wages? What if retrenchment is needed because the plantation harvest is low?

290 might have strong opposition from the social movements if the plantations would cause any unfair treatments to the community such as health issue, illegal/child/forced labour detected, disqualifying environmental issues due to agrochemical pollutions, or the opposition party of the host government who is against the plantation projects due to the massive change on land use.

(b) Land Use for the 2G Biofuels

Although, it is scientifically proven that the 2G lignocellulosic biofuels like miscanthus, switchgrass, jatropha could be grown on marginal/idle land; the fact is, these biomass still acquired land for growing. Besides, the oil companies might not have the full authority to decide on the exact idle land use for biomass growing as it is still much depend upon the host government in land planning (policy and execution), as well as their involvement in ensuring that the genuine set-aside land has been utilise for feedstock growing. Therefore, this raised another challenge for oil companies on the large-scale 2G feedstock plantations. Collaboration between the oil companies and the local government is vital, in order to ensure what has been claimed for the G&S of the 2G biofuels could be really achieved. The idle land has to be measured and then occupied for the feedstocks growing.

(c) Environmental Implications for Algae

Algae is an advanced technology which could be grown through a sea farming technique. Even though algae has the potential to produce biofuels with higher GHG savings, the large-scale growing of algae; if mismanagement took place, it could result in ocean pollution that would threaten the marine life[291]. Therefore, a precautionary principle has to be in place, in order to access the socioenvironmental implications thoroughly for such a technology, to avoid algae pollution from happening.

291 Algae have killed entire reef structures. The mats of algae suffocated coral, sponges and other marine life underwater (Fine, 18 July, 2010).

Chapter 8 Conclusion

This research is aimed at gaining an insight into a large social technology (biofuels), which is experiencing a dynamic technological change, when it is under the processes of deployment and development. Consequently, different types of R&U (expected/unexpected R&U) emerged. Evidenced by counteracting strategies implemented by the regulators and the oil companies, their aims were to ensure the resolution and to mitigate these R&U, by setting a path for the ease of biofuels execution and innovation.

8.1 Driving Forces for the Governments and the Oil Companies in Biofuels Adoption

Biofuels activation was due to the EU/UK Governments' mandate. Through regional and national policy formulation, these governments have implemented the 1G biofuels. Since the EU/UK and the Scottish Government (SG) were involved in the regional/national biofuels adoption, the commencement of biofuels was driven by the respective objectives of these regulators. This research shows, there were three political motives to drive regional/national biofuels adoption:

(a) The regional/national aim for greenhouse gases (GHGs) reduction from the road transport system.

(b) The regional/national interest to achieve “partial” energy security.

(c) To prosper the regional/national economy, gradually switching from an oil-dominated-economy, towards a green economy.

The oil companies' involvement in biofuels businesses was mainly driven by their economic interests. There were three driving forces identified, which led BP and Shell to enter the biofuels businesses.

(a) Challenges in energy sourcing

Since hydrocarbon is sourced from politically unstable regions, this could affect their long-term business operations. Besides, hydrocarbon is a depleting resource. Therefore, the renewable criterion exhibited by biofuels is an attractive option, which can help to alleviate the pressures on increasing energy demands. Besides, biofuels can prolong the oil companies' energy business, to be included as one of the energy profiles.

(b) Increasing pressure on combating climate change through low-carbon energy supply

The international/regional/national policies are emphasising on combating climate change. Therefore, cutting GHG/CO_2 emissions is one of the core objectives of energy providers. The oil companies are obliged under the regulations and driven by corporate social responsibility-to ensure the energy product they supply, as well as the processes to generate the energy product are low-carbon, less polluting and more environmental friendly; in order to improve their green image.

(c) The long-term business interest of biofuels is supported by the mandatory requirements from the regional/national regulators.

Since biofuels implementation is guided by the regional/national mandates, biofuels are one of the most lucrative energy businesses. Facing a range of possible new energy sources, the oil companies have many practical reasons[292] to invest and pursue the next generation biofuels (NGB) R&D for their long-term business objectives. This is to ensure that the NGB will comply with green and sustainable (G&S) criteria, and have higher productivity to meet the increasing demand.

The research points out that, biofuels are at the conjunction of interests between the regulators and the oil companies, on which these two actors are working hand-in-hand to have biofuels implemented and further developed. Given the commitments of the EU/UK governments to biofuels as the regional/national policies; in the UK, biofuels have been prioritised for CO_2/GHG reduction for its domestic road transport system.

292 Lower switching cost, compatibility of biofuels with the existing hydrocarbon infrastructure, biofuels can be blended with hydrocarbon (petrol/diesel), and adopted in the internal combustion engines (ICEs) without any modification.

8.2 Roles and Responsibilities of the Governments and the Oil Companies in Biofuels Deployment and Development

Since the UK is a unitary state with a devolved system of governance, the UK biofuels deployment is determined by the UK Government and influenced by the EU. Therefore, biofuels adoption in Scotland is not a single cell operation of the SG. The influence of the EU/UK Governments signifies the multiple roles the SG plays-not only as the regulator in Scotland, but also the executor of biofuels implementation in Scotland.

During the policy-making processes, most of the decisions are made at the EU. Then, decision is transposed to the respective member states like the UK. At the national level, the UK Government liaises with the devolved governments like the SG, and passes the regulatory decisions made[293] to the oil companies-whom are acting as the biofuels suppliers. The UK Government is responsible for the planning and the execution of the national biofuels policy. Besides, it also has to ensure that the SG is adopting the national biofuels policy; while monitors the oil companies' performance, in supplying biofuels which comply with the Renewable Transport Fuel Obligation (RTFO) 2008.

Compared with the UK Government, the SG adopted a more progressive approach in the NGB development. Various major research projects taking place in Scotland, as well as pioneer works established[294] are supported jointly by the EU/UK/SG which reflected by various Scottish policies[295].

Meanwhile, the oil companies, like BP and Shell, have been responding proactively to the biofuels demands by the UK Government. Both companies are committed to consistent biofuels supply, which is guided by the mandatory targets of the RTFO.

293 Information is appeared in the form of policies, directives, acts, regulations, standards and mandatory targets of biofuels under the RTFO (2008).
294 the UK first biodiesel plant and the UK first biofuels research centre in Napier University.
295 Biomass Action Plan for Scotland (2007), Scotland's Consultation on Low-Carbon Vehicles (2009) and Scotland's Renewable Action Plan (2009).

Funded by their own (private) investments, BP and Shell are two of the world six oil companies which currently are embarking on the NGB research. The pioneering status is important for both BP and Shell. This is because, such status would enable them to secure the lucrative long-term biofuels business prospects. This research points out that, operating under the current regulatory framework and the market system, political and business forces have been converged at the context of regulated market which allows biofuels to be implemented and developed. This collaboration is operating efficiently to achieve the predetermined targets.

8.3 Mechanisms which Deliver Biofuels Deployment and Development

Apart from the RTFO which acts as a guidance for biofuels deployment, an agency is established by the Department for Transport (DfT). The Renewable Fuel Agency (RFA) is empowered by the DfT, to monitor biofuels deployment in the UK. In order to control biofuels deployment, various regulatory instruments have been instituted. These include:

(a) The RFA rules and regulations, requires all the oil companies/biofuels suppliers to report monthly on the “Carbon and Sustainability” reporting system;

(b) The RFA enforced the Renewable Transport Fuel (RTF) Certificate which acts like a business licence for biofuels trade and supply within the UK market;

(c) European standards on biofuels quality control-Biodiesel EN14214, and Bioethanol EN15376;

(d) Mandatory annual targets of the RTFO (2008);

(e) Fuel Duty Incentives-20p/litre on biofuels.

Furthermore, the vehicle manufacturers provide the standard warranty to be remained intact voluntarily, where biofuels are mixed with mineral fuel at a rate of maximum 5% by volume used in the ICEs. The oil companies/biofuels suppliers gained the incentives to achieve cost efficiency. Meanwhile, they ensure their products comply with the biofuels European standards, follow the RTFO targets and submit their biofuels report every month to the RFA for the “Carbon and Sustainability” reporting system.

For the NGB development, the UK and the SG are leading by example, by investing in the nationwide NGB R&D projects. Combined funds from the EU/UK/SG are injected into academic institutions, public agencies and local private sectors, to carry out the NGB research and infrastructure set-up, such as production plants and research centres. Besides, updated national policies [296] are published and made available to the general public, in order to highlight the importance of the G&S biofuels as one of the Renewable Energy for Transport (REfT).

The EURED (2009) requires 10% of transport fuels must consist of renewables by year 2020, has enhanced the corporate confidence in biofuels businesses, despite large amount of resources and high risks involved in the NGB R&D projects. Furthermore, the stringent biofuels G&S criteria are gradually required for the "Carbon and Sustainability" reporting system, which is guided by Meta/Qualifying standards and controlled by the RTF certification. In order to reward the genuine G&S biofuels, by year 2011, the UK Government will incentivise biofuels that meet all the G&S criteria (Meta standard) outlined by the RFA. Looking at the mechanisms applied and the strategies implemented, these methods were playing multiple roles. On one hand, they are set to facilitate biofuels introduction and innovation; while on the other hand, they were established as the risk preventive strategies to mitigate any anticipated R&U to ease the processes of biofuels execution and innovation.

8.4 Risk and Uncertainty Arising during Biofuels Deployment and Strategy Implemented to Counteract

This research is aimed at gaining an insight into a large social technology (biofuels), which is experiencing a dynamic technological change, when it is under the processes of deployment and development. Due to the dynamic technological changes, different types of R&U (expected/unexpected R&U) emerged during these two processes. Several expected R&U have been identified by Rosenbloom and

296 The UK Powering Future Vehicles Strategy (2001), the UK RTFO (2008), Scotland's Consultation on Low-Carbon Vehicles (2009) and Scotland's Renewable Action Plan (2009).

Kantrow (1982), Pearson (1991), Rosenberg (1994) Elliott (2003) and the report from SpecialChem (2011). These literatures helped to make the identifications of the expected R&U during biofuels implementation and innovation easier. The R&U faced by the regulators during biofuels deployment and the strategies taken to counteract were:

(a) Political support

Strategy: Strong political support and adequate follow through during biofuels deployment.

Biofuels deployment gained clear political direction from the EU which has formulated the EUBD (2003) and the EURED (2009). These then being transposed to its member states-the UK, to deploy biofuels for the nationwide road transport system. The RFA was established to execute the RTFO (2008), and to monitor the G&S biofuels supply in the domestic market. The SG involvement for biofuels implementation is obligated under the UK Reserved Matters.

The deployment process is guided by the national/regional targets, biofuels unified standards and is backed by the regional political decision. Therefore, this show that the EU/UK Governments and the SG have undertaken vigorous measure to establish the biofuels policies which are stable, transparent and with well-defined objective that executable/implementable under the energy market (criteria as advocated by Mallon, 2006). The requisite R&U involved the allocation of responsibilities between the regional/national policy makers to deal with various aspects of strategy. Any R&U faced by the member states, could be brought to the EU for further discussions.

(b) Investment

Strategy: Adequate an adequate financial support on biofuels adoption.

Biofuels are taxed at 20p/litre less than petrol and diesel, which aimed to ensure that, biofuels are cost effective.

Strategy: Low investments/switching costs required for biofuels adoption.

Biofuels provide the most economical solution, with low switching costs involved. The compatibility of biofuels with hydrocarbon, not only have secured the low operation costs, but also allowed them to be adopted/used at the existing hydrocarbon infrastructure and ICEs. The technical convenience encouraged biofuels adoption with immediate effect.

(c) Social acceptance

Strategy: Many of the OECD countries have showed their support on biofuels adoption. In order to promote the benefits of biofuels, the positive social, economic and environmental impacts of biofuels are being promoted through government/organisational media as the public education-advocated by Baron (2011).

(d) Biofuels Technical performance

Strategy: High reliability of biofuels performance.

Biofuels have been proven on their practicality and executability. They have been implemented in the US for nearly five years and in Brazil for more than three decades. Biofuels are compatible with the existing hydrocarbon supply infrastructure and ICEs, which allow for an immediate adoption.

(e) Institutional interests

Strategy: Biofuels create some positive impacts on other institutions.

Biofuels do not compete with other types of REfT such as H_2 and electricity. They are complementing each other to support the future transport energy demand. The 1G biofuels generates wealth on the agricultural industry. The NGB development magnetised the biotechnology institutions and the oil companies for profits seeking.

Meanwhile, the R&U faced by the oil companies during biofuels deployment and the strategies taken to counteract were:

(a) Weaknesses of the 1G bioethanol

Strategy: To overcome the limitations of the 1G bioethanol, BP is developing biobutanol with DuPont, while Shell is developing biogasoline with Virent.

(b) Stringent requirements on the G&S biofuels

Strategy: To comply to the G&S criteria of biofuels, BP and Shell supply biofuels according to the RTFO targets, and report monthly under the RFA "Carbon and Sustainability" reporting system. Both companies are complying with the Meta/Qualifying Standards set by the RFA. Furthermore, both companies have participated as the members in various roundtables.

Shell has a stricter control for its biofuels product, production and supply. It established the Sustainable Sourcing Policy (SSP) in order to control its biofuels suppliers adhere to the stringent biofuels G&S criteria. This allows Shell to obtain more reliable information, and could provide more accurate information when reporting to the RFA.

(c) Low social acceptance of biofuels adoption

Strategy: Biofuels which are renewable and capable to reduce GHG/CO_2 emission from vehicle tailpipe are promoted through corporate websites. Besides, the technical conveniences have overcome the consumer worries advocated by SpecialChem (2011) report on reliability, scalability and future availability.

8.4.1 Two Systemic Risks Incurred during Biofuels Deployment

There were two systemic risks: food-fuel competition and biodiversity threatened, occurred during the 1G biofuels deployment, and resulted in pressure on the regulators and the oil companies.

During this period, these systemic risks were amplified by pressure groups and the international/local broadcasting/print media. Facing the challenges from the systemic risks resulted by the 1G biofuels deployment, the oil companies and the policy makers have been finding new strategies to mitigate them. The regulators (the EU/UK/Scottish Government), BP and Shell did not launch a direct confrontation or media-war with the pressure groups and the media. Strategically, through their own organisational media (mainly websites), they focused on disseminating of the NGB information. Furthermore, they concentrated to ensure the existing 1G biofuels is produced and supplied in the G&S ways. This information was supported by the independent/reputable organisations-learned societies (such as WorldWatch Institute, The UK Royal Society and others) that are acting as the scientific knowledge broadcasters. These learned societies periodically publish the latest information/development about the NGB technology.

To deal with these two systemic risks, an investigation was called by the UK Government. Consequently, the investigation that led by Professor Gallagher resulted in the Gallagher Review (2008) was published; which subsequently rendered to the alteration of the RTFO targets to slow down biofuels expansion. Because of the systemic risks, new forces emerged. This research shows an institutional and power switched from the regulators and the oil companies, to pressure groups such as the international/national social movements, environmentalists and the media. These pressure groups expressed new demand for the enforcement of the G&S biofuels criteria emphasised on biofuels products, production and supply. Such requirements not only changed the existing 1G biofuels supply chain (in order to prioritise socioenvironmental objectives); but have also shaped the NGB development (on products and production) to be more G&S oriented.

In addition, the EU/UK Governments started to enforce the biofuels G&S criteria. A more stringent biofuels “Carbon and Sustainability” reporting system with “Indicative Targets” (refer section 4.1.2) was established. This was to ensure that biofuels used in the UK are capable to exhibit/fulfil the G&S criteria which specified by the RFA Meta/Qualifying standards. In order to rebuild social acceptance of biofuels, more information about the NGB R&D projects, as well as the G&S criteria/benefits of the NGB have been introduced through organisational media (the regulators' and the oil companies' own websites). Besides, the monthly "Carbon and Sustainability" report was published by the RFA, whereby these reports[297] were available to the general.

8.5 Risk and Uncertainty Arising during Biofuels Development and Strategy Implemented to Counteract

The R&U faced by the regulators during biofuels development and the strategies adopted to counteract were:

(i) Political support

Strategy: The SG has a strong vision for the NGB development, which was backed by the regional/national biofuels policies. The SG has formulated the Renewables Action Plan (2009), took in the NGB as one of the focuses for national RE development.

(ii) Funding

Strategy: The NGB R&D projects are running independently, being funded by the regulators (the EU/UK/SG combined financial strength) and the oil companies separately. There was no reliance by the private sector on government funding.

(iii) Situational

Strategy: Right time and right scenario in combating climate change, green economy evolution, and to avoid the occurrence of systemic risks through the NGB development. The G&S criteria of the NGB are promoted through the governments', the oil companies' and independent institutions' organisational media to inform the general.

(iv) Technology expectations and performances

Strategy: The main function of biofuels used in the UK is to reduce road transport GHG/CO_2 emissions. The NGB technology has to continue to perform this role, or

297 to show the data/information/results of biofuels executed by the biofuels suppliers/oil companies, and how far the G&S criteria have been complied by them.

even be better to reduce the carbon footprint from farm-to-wheel cycle. Ultimately, the NGB must demonstrate the better G&S criteria to safeguard the socioenvironmental benefits.

(v) Institutional interests

Strategy: Since biofuels adoption was a political mandate, no evidence was found on the confrontation of biofuels among the EU, the UK Government and the SG. On the other hand, there were a few of the NGB R&D projects in Scotland which obtained funding from the EU/UK Governments. These showed the EU/UK converged political interest and financial support on the NGB development in Scotland. Besides, the oil companies were seeing biofuels as one of the most lucrative business opportunities that could sustain their energy business.

Meanwhile R&U faced by the oil companies during biofuels development and the strategies implemented to counteract were:

(i) Uncertainty about the NGB technological outcomes

Strategy: BP and Shell are working as close as possible to the nine criteria/requirements laid out.

(ii) Beyond the oil companies' institutional knowledge and capabilities in the NGB development/production.

Strategy: BP and Shell collaborated on a few R&D projects with their respective biotechnology and agricultural partners. This is one of the risk transfer strategies, which the oil companies are transferring their inadequacy in knowledge and production capability to the experts-the biotechnology institutions and the agricultural industry who are capable in doing so.

(iii) Low social acceptance of the NGB technology.

Strategy: In introducing the NGB to a risk adverse market, the oil companies are promoting the benefits and the G&S criteria of the NGB to the general public through their own organisational media (mostly website). The latest information on the industrial research and the NGB research are also shared to the market through their websites. Additionally, Shell is using motor racing events as the test bed for its NGB. By providing information about the technical specificities of the NGB, consumers are well-informed with this technology and be confident on the NGB adoption in the near future.

8.6 Social Construction of Technological Risks

Since technology is a social product, the technological risk does not develop from a technical logic. Instead it is shaped and influenced by intricate social forces and social network involved. A new technology which is innovated and then implemented in a large social technical system carries various R&U may generate many negative consequences. Although the new technology is meant to reduce the existing R&U[298] or to overcome particular problems, it may create new R&U to society and the environment if mismanagement takes place.

This research provides a social discourse of the R&U involved in the processes of biofuels deployment and development. Hence, this research demonstrates:

(a) R&U are socially constructed.

(b) Politics and economic systems are powerful mechanisms to deliver technology implementation and innovation. However, mismanagement[299] together with other regional/national social disparities[300] are shaping R&U from a specific technology.

(c) The perceptions about R&U are different among different stakeholders. Misunderstanding and gaps in current knowledge may contribute to the creation of new R&U.

It is evidenced that the prioritisation of biofuels as one of the REfT is derived from

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298 For example biofuels adoption is to reduce the risk of climate change and to restore energy security.

299 Political rush for biofuels implementation, inadequate risk assessment which have failed to consolidate risk precautionary principles. Besides, many of the policies have ignored the issues of land use planning as well as to equalise the community risk and cost-benefit distribution.

300 Different social context for biofuels adoption. Biofuels which are successful in one social setting might not as successful in another social context.

the converged interests of the governments and the oil companies. Given a wide range of possible alternate REfTs associated with social and technical R&U, the assessment and the perceptions of R&U are largely determined by political, social and economic systems which are influenced by these powerful stakeholders. The oil companies' pursuance on the 1G biofuels is focusing on the grains-derived fuels. Driven by economic motivation to maximise profit through the economies of scale, this has resulted in a large-scale production of biofuels. A limited domestic production capability was stretched to fulfil the unlimited global biofuels demands. This then caused the emergence of systemic risks at food-fuel competition, and biodiversity threatened in biofuels farming/producing countries.

8.7 Risk Perceptions and Precautionary Principle

Under a large social technology deployment and development, the scope and nature of the expected/unexpected R&U are becoming more complex. Consequently, strategies adopted to deal with them are getting more challenging. The research points out that, the stakeholders/decision makers need to consider different risk perceptions, and to facilitate mechanisms with more precautionary principles for decision-making and decision-execution.

This research shows that, the risk perceptions were different among the stakeholders[301]. This was mainly due to each of their-own perceived risk, but not the risk they estimated others to perceive. Biofuels mean differently to different stakeholders involved. Each of them perceives biofuels based on their knowledge and interests respectively.

The governments tended to focus on the impacts on their policies formulated. They feared the failure to achieve the mandatory GHG/CO_2 reduction targets and the regional biofuels targets (EUBD 2003 and EURED 2009). Meanwhile, the oil companies worried about the possible losses in taking up this new business,

301 the regional/national policy makers, the oil companies, the biofuels producers/farmers/suppliers, the general public and the pressure groups.

particularly the NGB R&D projects which involve high risks and high investments. What these two actors concerned with their own political and economic gains respectively, had not envisaged the fear which the general public had regard to food security and ecology protection.

In order to build up the converged risk perceptions at an earlier stage, as well as to facilitate the precautionary principles, Renn (2008) advocates that risk pre-assessment shall take into account the public opinions/responses in all stages along the decision-making and decision-execution processes. Knowing the public values/concerns helps to detect new/emerging R&U earlier, to provide some initial insight into the extent/severity of these R&U and also to determine whether a decision should be executed after considering the implications.

The precautionary principle allows the policy makers to adjust their decisions in situations where there is the possibility of harm/risk from following a particular course, or making a certain decision when the extensive scientific knowledge on the matter is lacking. The principle implies that there is a social responsibility to protect the public from exposure to harm/losses. The risks information collected could then be pre-screened and allocated to different assessment and management routes. For this reason, the regulators should establish a risk communication channel in order to collect public response. A two-way communication (between the general public and the regulator) is important to avoid the disparity between the regulators' and the public risk perceptions. If this could be performed beforehand, the unexpected R&U or systemic risk occurred during the 1GT biofuels deployment could have been avoided.

Regardless of the different stakeholders with different standpoints on particular decisions, there should always be a prioritisation, particularly in a large social technical system that associates with the public general welfare. Apart from fulfilling each of the stakeholders' interests, the ultimate objective in welfare economics (like biofuels adoption), is to safeguard the large public interest in social, economic and environmental benefits. When there is a conflict among the stakeholders, then the public interest should be prevailed in order to protect the poor and vulnerable.

8.8 Social Shaping of Criteria/Requirements for the Next Generation Biofuels

This research shows that during the process of biofuels deployment and development, the UK Government, the SG and the oil companies (BP and Shell) had to respond to pressure from social groups, to launch the strategies in meeting the G&S biofuels criteria. After the systemic risks, the scenario showed an institutional and power switch-from the regulators and the oil companies, to pressure groups such as the social movements and the environmentalists. These pressure groups came out with a new demand for the enforcement of the G&S biofuels criteria, targeting on biofuels product, production and supply. This requirement not only changed the existing biofuels supply chain, by prioritising on the socioenvironmental sustainability; but also in shaping the NGB products and production which are still under the development process.

The nine criteria/requirements (refer 7.4.1) seem to provide a set of clearer yardstick for the NGB development. They cover the areas of:

(a) Solving the limitations/weaknesses of the 1G biofuels.

(b) Adopting new inputs learned from the emergence of two systemic risks which the biofuels G&S criteria have to be prioritised and enforced.

(c) Respective interests of stakeholders.

Generally, these nine criteria/requirements are shaped by the various stakeholders-the regulators, the oil companies, the biofuels players and the pressure groups. Concentrating on the G&S criteria for biofuels, the NGB has been largely shaped, not only to allow the pursuance of biofuels for political and socioeconomic benefits, but also to safeguard the socioenvironmental welfares. Along with this, these social actors are influencing the content of the NGB technology and its social implications.

8.9 Lessons Learnt from Biofuels Deployment and Development

The purpose of this section is to bring together any lessons learned during the technological change under biofuels deployment and development processes. This information could be usefully applied to any similar RE project which may also encounter a technological change for its technology implementation and innovation. The values lie, not only for the current application, but also for future practices, to give recommendations and to highlight precautions on issues which require further enhancements/modifications.

8.9.1 Capacity, Green and Sustainability

We would foresee biofuels are possible to be expanded and fuelling other modes of transport include an aviation and shipping after some duration of biofuels implementation. If this could be achieved, the more efficient use of low-carbon energy in powering a bigger transport landscape could be materialised.

However, there are three important criteria for a REfT: Capacity, Green and Sustainability. Biofuels are currently being challenged on their G&S criteria. The systemic risks provide the evidence of-not only the inadequacy of the G&S criteria, but also the limited agricultural capacity of the 1G biofuels to fulfil the unlimited demand. Consequently, food security and the environment were victimised. Although after the NGB were commercially available-which "theoretically" promises to deliver the G&S biofuels; we could foresee the issue of growing demand would still continue to pose a challenge to the capacity of the NGB.

Consequently, the existing biofuels and the forthcoming NGB should not be expected as the sole energy source, which could support the entire world/national transport system. This is because no single REfT would have such capacity, be able to replace/substitute the hydrocarbon totally. The bottom line is, since RE is the energy generated from natural resources, the RE generation should not cause any negative impact on social and ecology. RE once developed and deployed, not only needs to surpass the technical constraints, but also has to sieve through the social requirements, at least to safeguard the socioenvironmental benefits.

8.9.2 Towards a Sustainable Transport System

Due to the major R&U surrounding technological change, forecasting the future of biofuels production-and-use with confidence is extremely difficult. This highlights the importance of adopting an approach that ensures sufficient flexibility has to be remained for the market to respond to any changing circumstances.

For the long run, a range of different fuels will be in operations, simultaneously supporting the EURED (2009) which requires 10% of renewable transport fuels by 2020. Currently, solar/electric/H_2 powered vehicles are still a long way from achieving significant market penetration. Despite the front runner position of biofuels, they are unlikely to represent the dominant part of a fuel mix, due to land and agricultural constraints. Perhaps, it is not only the “types of vehicle” that would determine “the types of fuel” used. Firstly, different fuels may suit different purposes. For example, the concentrated availability of electric charging points in the city centre and the frequent recharging required of an electric car may make it more suited to city trips. Meanwhile large trucks/buses/air planes may require H_2 for long journey use since the fuel could be compressed and do not put an additional weight on the vehicles. Biofuels are there to cater for the shipping industry, to power the existing ICEs and the flex-fuel vehicles.

Secondly, the niche availability of energy sources may make some of the fuels suited to certain geographic areas. For example, areas that are equipped with RE resources like Scotland, might find it more cost effective to use electric and flex-fuel vehicles. Brazil and the US could continue their biofuels vehicles, while in equatorial countries; solar vehicles could be more suitable. Therefore, a diversified REfT profile consisting of H_2, electricity, solar power and biofuels would enable the energy sources to complement one another. Their existence could fulfil future energy demand and provide more choices for consumers (based on different types of vehicles which require different types of REfT).

Even though, theoretically, different types of RE could potentially meet the increasing global energy demands for transport, and reduce the overall GHG/CO_2 emissions; the energy consumption must also be paired with greater efficiency of automobile technologies, as well as consumers' attitudes. Consumers should have a higher sense of energy sensitivity, and show a willingness to make minor behavioural changes based on environmental ethics. Any actions to reduce energy use, such as: cycling/walking for short distance travel, or opting for public transport when undertaking a longer journey is encouraged. These willing efforts, combined with the low-carbon fuels and the efficient automobile technologies, all would contribute to the low-carbon equation and ensure the overall sustainability of the transport system is achievable.

8.9.3 Marginal/Idle Land Utilisation for the 2G Biofuels

According to Gallagher (2008), the current policies have failed to ensure that biofuels feedstocks are genuinely grown from the set-aside/idle lands. The invasion on farms and high biodiversity areas happened to give way for biofuels crops.

Theoretically, the 2G lignocellulosic biofuels like miscanthus/switchgrass/jatropha could be grown on marginal/idle land, which can eliminate competition with farms. Yet, these biomasses still acquire land for growing. In any case, the oil companies as the cross-border project investors, mostly do not have the full authority to decide which idle land could be used (in the host countries) where plantations are set. Furthermore, it is hard to ensure that every litre of biofuels is sourced away from high biodiversity areas, and genuinely being produced on specific land that set aside for this purpose. As such, this poses another challenge for the oil companies on a large-scale/cross-border plantation.

Hence, much remains dependent on the host government's land planning, to ensure genuine marginal land has been utilised for the feedstocks growing. Collaboration between the oil companies, the local government and the roundtables is vital. This is to ensure what has been claimed for the G&S of the 2G biofuels can be truly achieved.

To stop this from happening, there is a need for more comprehensive rules and regulations set by the host country to be instituted. The feedstocks growing process has to be monitored by the third party such as roundtables, apart from their current roles merely in formulating Principle and Criteria (P&C) for sustainable biofuels. The roundtables should be independent, aggressive and put those P&C into action. Only through the participation of these stakeholders, the actual marginal lands can be appropriately utilised, to materialise the G&S biofuels production.

8.9.4 Transportation of Biofuels in Trade

Compared with other types of REfT (H_2/electricity), biofuels exhibit the positive carbon neutrality which can absorb CO_2 from the atmosphere during photosynthesis. Despite having very low emissions, alternatives such as H_2/electricity do not recycle CO_2 in the atmosphere.

To equip biofuels with carbon neutrality, highly energy efficient fuel crops, well-planned land use and well-managed farm-to-production activities are playing their part in the carbon equation. If these activities can be managed well with full integration: to minimise the CO_2 release (by minimising energy input); by avoiding the conversion of high biodiversity lands for biofuels plantations; and choosing high-yield feedstocks which portray a sustainable criteria; all of these would lead to significant carbon savings.

However, until this stage, there is still one missing activity which has not been accounted for in the carbon equation-the transportation of biofuels through international trade. Moving biofuels across borders is not only expensive, but it also increases global GHG/CO_2 emissions during the transportation. This issue should be tackled by the related stakeholders, and it needs to be considered for more comprehensive GHG/CO_2 savings.

8.9.5 Corn Roundtable

The roundtable's principle and criteria (P&C) is to act as a control mechanism, to ensure biofuels supplied are G&S in products, production and supply. The P&C guide the front-line people such as farmers, producers, traders do on the ground in the activities of growing feedstocks, manufacturing biofuels and trading, in order to comply with the G&S criteria laid out.

To date, there are four biofuels roundtables[302] established, but there is still no roundtable for corn. The researcher proposes, in near future, any kind of feedstocks should establish its own roundtable; or at least, to adopt the general P&C advocate by the Roundtable for Sustainable Biofuels (RSB) in order to materialise the G&S biofuels products, productions and supply.

8.9.6 The Socioenvironmental Implications of Algae

One of the main benefits of algae-an advanced 3G biofuels technology is that, it could be grown through a sea farming technique that minimises the land use. Although algae has the potential to produce large quantities of biofuels with higher GHG savings; the massive scale of growing algae, if mismanaged, could lead to ocean pollution and pose a threat to marine life. Therefore, the precautionary principle has to be instituted, to assess the socioenvironmental implications thoroughly before this technology is used for commercial scale production. This is to avoid algae pollution, another form of systemic risk from happening.

8.9.7 Expansion of Criteria/Requirements for the Next Generation Biofuels Development

The NGB technology within the nine criteria/requirements presents a set of prerequisites for the "eligibility", the achievement of which poses numerous challenges for scientists/engineers involved. They must try to balance the global advantages of renewables against the local impacts, and come up with technically

302 the Roundtable for Sustainable Biofuels (RSB), the Roundtable on Sustainable Palm Oil (RSPO), the Roundtable for Responsible Soy (RTRS) and the Better Sugarcane Initiative (BSI).

workable, economically viable and environmentally acceptable compromises. The bottom line is, a new technology like the NGB needs to pass a socioenvironmental test, not just an economic and a technological one.

Generally, these nine criteria/requirements have some degree of continuity. They do not appear as completely static or set in stone. This complies with the nature of technological innovation/change, which is dynamic and evolving. Therefore, for the time being, these nine criteria provide a yardstick for the NGB R&D. We can expect further expansion of these nine criteria/requirements through continual assessments from the 1G biofuels deployment, and any new requirements from any related stakeholders.

8.10 Limitations of this Research

The processes of biofuels deployment and development are continuous, dynamic and evolving. These show that, the technological change that takes place within these two processes is complex, highly uncertain and challenging. Even though the validity and reliability of this research have been assessed (in Chapter 3), the study has its limitations. The study examined the SG (with its relationship with the EU/UK Governments) and the two oil companies (BP and Shell) on biofuels deployment and development. As such, these findings cannot be over-generalised.

Theoretically, the concept of a biofuels regulated market is extended from an oil regulated market. In fact, the biofuels regulated market is still under-researched. The research was slightly impaired by the lack of relevant literature-which study a RE adoption/innovation from a social science and management perspective. In addition, there was a scarcity of literature to investigate the large-scale risk associates with the deployment and development processes of a new technology.

All of these left some loopholes, where many theoretical concepts were either under-researched, restricted to ordinary market technology, or based on conventional corporate risk strategy. Therefore, using this literature that available to understand a large social technology execution/innovation under a regulated market; R&U associated with technological change, the emergence of systemic risk and the political/corporate strategies required to deal with them; was indeed challenging.

Since this research is a green field, in order to strengthen the research concepts, different types of literature were searched to complement one another. Social Shaping Technology (SST) is used to help the understanding by mapping out the actors; to examine the interactions between these actors; to investigate the content of technology; the processes of technology implementation/innovation, and to identify R&U arising during technological change.

The Risk Governance advocated by Renn (2008) and the Risk Regulated Regime advocated by Hood et al. (2004) were integrated with SST. Consequently, an interdisciplinary concept was developed. This concept was built, to correlate the social shaping of one technology, and social construction of technology related R&U rendered by technological change. Meanwhile, risk governance and political strategies were integrated, to deal with these expected/unexpected R&U in a more systematic manner. In other words, the application of SST is to broaden the risk governance and risk regulated regime, thereby to facilitate the study of R&U associated with technological change from a social dimension.

This research which investigated technological change during a large social technology deployment and development processes was indeed complex, uncertain and continuously evolving. The research could be analogised as "trying to collect these riches, is like holding a bucket under a waterfall"-Hamish Handerson (1960). What the researcher has captured and presented in this study was indeed limited. Yet the researcher believes, the potential/contributions of RE development and deployment under the theoretical sphere of SST, risk governance and risk regulated regime are enormous and inspiring.

8.11 Suggestions for Future Research

Since a single PhD research project is, by nature, restricted to what can be accomplished in four-year-time, this section highlights some potential areas that can be used as ideas for further research.

(a) There are two models resulting from this research. Model one depicts the interplay of the respective stakeholders to commence the 1G biofuels deployment in the UK. Meanwhile, Model two describes the social shaping nine criteria/requirements for the NGB development. Both have pictured the existing scenario leading to biofuels implementation in the UK, as well as the future context which is guiding and shaping the NGB.

These two models would provide some potential topics in the near future. Model one could be used, to investigate additional mechanisms, or the emergence of any new actor (for example automobile industry, independent agriculture industry), which would influence the regional/national biofuels continuation. Meanwhile, Model two allows for further examination on emerging criteria for the NGB development. We could expect some new criteria to be added to the existing one, not only to materialise the respective interests of the stakeholders, but also to ensure that the NGB could be technically workable, economically viable and environmentally acceptable.

(b) The regulators' political authority and the oil companies' business strategy in risk governance would also evolve over time. Some new types of R&U would emerge, which would require different types of strategy and control/preventive mechanism.

This research has investigated the 1G biofuels deployment, while analysing the NGB development which is currently ongoing. It is estimated that after the year 2015, when the NGB technologies are commercially available, we can expect a new landscape on the NGB deployment which will cause new political, social, economic and environmental implications. The rule of thumb is: technology, once developed or implemented, not only react back upon their environments, but also generate new implications (Clark and Staunton, 1989; Fleck, 1993). Thus, the various stages in the NGB development to its deployment, provides some interesting topics where further research can be undertaken.

References

1. Adams, J., 1995. Risk. UCL Press.
2. An interview conducted with Shell Biofuels Sustainability Compliance Officer, on Tuesday 30 June 2009 located in London.
3. An interview conducted with the Engineer of the Renewable Energy Team, on Monday 20 October 2008, located in London Office.
4. An interview conducted with the Executive in the Shell CO2 Abatement Project, on Friday 17 October 2008, located in London Office.
5. An interview conducted with the Procurement Executive, on Saturday 18 October 2008, located in London.
6. An interview conducted with the Quality Engineer, on Monday 20 October 2008, located in London.
7. An interview done with the Executive of Corporate Services Team, Communications Directorate, on Monday, 22 September 2008, located at the Scottish Government St. Andrews House, Edinburgh, Scotland.
8. An interview done with the Executive of North Western Europe Exchange Project, on Sunday 1 March 2009, located at London.
9. An interview done with the Executive of Renewable Policy Team, on Friday, 30 May 2008, located at Meridian Court, Glasgow, Scotland.
10. An interview done with the Executive of the Rural Directorate, on Thursday, 12 June 2008, located at Pentland House, Edinburgh, Scotland.
11. An interview done with the Fuel Engineer (under internship), on Wednesday 8 October 2008, located at Farburn Industrial Estate, Dyce Aberdeen.
12. An interview done with the Policy Manager of Cleaner Vehicles and Alternative Fuels, on Thursday 17 April 2008, located at Scottish Executive Victory Quay, Edinburgh, Scotland.
13. An interview done with the Public Relations Consultant of Argent Energy Ltd, on Monday 10 August 2009, located at the Argent office, Motherwell, Scotland.
14. An interview done with the Sustainability Strategy Manager, on Monday 8 October 2008, located at St James's Square, London.
15. Andreeva, G., Ansell, J. and Harrison, T., 2009. Politicians and Public Risk. Risk and Regulation Advisory Council.
16. Andrews-Speed, P., Liao, X. amd Dannreuther, R., 2002. The Strategic Implications of China's Energy Needs, Adelphi Paper 346, Oxford University Press.
17. Argent Energy, 10 March 2009. Green Pioneer Meets Minster to Explore Potential for Recycling. [Online]. Available at: http://www.argentenergy.com/articles/news/article_69.shtml [Accessed on 11 May 2009].
18. Argent Energy, 17 March 2009. World First for Scottish Green Fuel Firm. [Online]. Available at: http://www.argentenergy.com/articles/news/article_70.shtml [Accessed on 20 April 2009].
19. Argent Energy, 2006. Argent Energy Reaches Industry Milestone with Major Biodiesel Distribution Contract. [Online]. Available at:

http://www.argentenergy.com/articles/news/article_46.shtml [Accessed on 11 May 2009].

20. Argent Energy, 2008a. About Argent Energy. [Online]. Available at: http://www.argentenergy.com/index.asp [Accessed on 21 April 2008].
21. Argent Energy, 2008b. About Argent Energy. [Online]. Available at: http://www.argentenergy.com/eu_demonstration_project/life_cycle_analysis.asp [Accessed on 21 April 2008].
22. Argent Energy, 2009. About Biodiesel. [Online]. Available at: http://www.argentenergy.com/biodiesel/ [Accessed on 22 January 2009].
23. Arthur, W. B., 1989. Competing Technologies, Increasing Returns and Lock-in by Historical Events. The Economics Journal Vol. 99, (March), pp.116-131.
24. Assmann, D., Laumanns, U. and Uh, D., 2006. Renewable Energy: A Global Review of Technologies, Policies and Markets. Earthscan.
25. ASU Biodesign Institute, 2008. About the Institute. [Online]. Available at: http://www.biodesign.asu.edu/about [Accessed on 24 January 2008].
26. Atkins, A., 1 September 2010. Bold Action is Needed to Protect the Diversity of Life on Earth. [Online]. The Guardian. Available at: http://www.guardian.co.uk/environment/cif-green/2010/sep/01/biodiversity-factory-farming [Accessed on 1 September 2010].
27. Augustyn, H., 14 June 2007. A Burning Issue. [Online]. World Watch Institute. Available at: http://www.worldwatch.org/node/5136 [Accessed on 15 June 2007].
28. Aven, T., 2008. Risk Analysis: Assessing Uncertainties Beyond Expected Values and Probabilities. Wiley Blackwell.
29. Aven, T. and Vinnem, J. E., 2007. Risk Management: With Applications from the Offshore Petroleum Industry, Springer, Heidelberg and London.
30. Ayres, I and Braithwaite, J., 1992. Responsive Regulation: Transcending the Deregulation Debate. Oxford University Press.
31. Baker, T., 1999. Doing Social Research. McGraw-Hill Publishing.
32. Banks, E., 2009. Risk and Financial Catastrophe. Palgrave Macmillan.
33. Barac, C., Spencer, E. and Elliott, D., 1983. Public Awareness of Renewable Energy: A Pilot Study. International Journal of Ambient Energy, 4(4). pp. 199-211.
34. Barney, B., 2009. Emerging Risks. ERM Symposium.
35. Baron, N., 2011. Fresh Strategies for Introducing New Technologies to Risk-Averse, Frazzled Customers: Fast Company.
36. Barton, B., 2006. Safety, Risk and Adventure in Outdoor Activities. Sage Publications Ltd.
37. Baruch, F., Slovic, P., Lichtenstein, S., Read, S. and Combs, B., 2009. How Safe is Safe Enough? A Psychometric Study of Attitudes towards Technological Risks and Benefits. In Lofstedt, R. E. and Boholm, A. ed., 2009. Risk. Earthscan. pp. 87-112, Ch. 6.
38. BBC News, 27 November 2008. £65m Biofuel Plant Plan Shelved. [Online]. Available at: http://news.bbc.co.uk/1/hi/scotland/tayside_and_central/7752020.stm [Accessed on 12 December 2009].

39. BBC News, 1 February 2007. Mexicans Stage Tortilla Protest. [Online]. Available at: http://news.bbc.co.uk/1/hi/6319093.stm [Accessed on 1 February 2007].
40. BBC News, 14 March 2008. The Great Green Fuel Gamble. [Online]. Available at: http://news.bbc.co.uk/1/hi/business/7294516.stm
41. BBC News, 15 October 2008. Q&A: World Food Prices. [Online]. Available at: http://news.bbc.co.uk/1/hi/business/7340214.stm [Accessed on 15 October 2008].
42. BBC News, 16 February 2009. Offshore Wind Farm Sites Set Out. [Online] Available at: http://news.bbc.co.uk/1/hiscotland/7891197.stm [Accessed 16 February 2009].
43. BBC News, 18 April 2006. Growing Demand for non-food Crops. [Online]. Reported by Kinver, M. BBC News Science and Nature Reporter. Available at: http://news.bbc.co.uk/2/hi/science/nature/4914748.stm [Accessed on 24 Jan 2007].
44. BBC News, 22 September 2006. Biofuels: Green Energy or Grim Reaper. View Point by McNelley, J. A. [Online]. Available at: http://news.bbc.co.uk/1/hi/sci/tech/5369284.stm [Accessed on 27 January 2007].
45. BBC News, 23 March 2007. Biofuel Demand Makes Food Expensive. [Online]. Reported by Blythe, N. Business Correspondent News. Available at: http://news.bbc.co.uk/1/hi/business/6481029.stm [Accessed on 23 March 2007].
46. BBC News, 24 February 2008. Airline in First Biofuels Flight. [Online]. Available at: http://news.bbc.co.uk/1/hi/uk/7261214.stm [Accessed on 24 February 2008].
47. BBC News, 24 January 2007. Quick Guide: Biofuels. [Online]. Available at: http://news.bbc.co.uk/1/hi/sci/tech/6294133.stm [Accessed 24 January 2007].
48. BBC News, 24 March 2008. Call for Delay to Biofuels Policy. [Online]. Available at: http://news.bbc.co.uk/1/hi/sci/tech/7309099.stm [Accessed on 24 March 2008]
49. BBC News, 26 August 2008. UK Should End Biofuel Subsidies. [Online]. Available at: http://news.bbc.co.uk/1/hi/uk/7581436.stm [Accessed on 26 August 2008].
50. BBC News, 29 June 2007. Charity Attacks Rush for Biofuels. [Online]. Available at: http://news.bbc.co.uk/1/hi/sci/tech/6252594.stm [Accessed on 30 June 2007].
51. BBC News, 29 May 2008. Long Era of Cheap Food is Over. [Online]. Reported by Loyn, D. Available at: http://news.bbc.co.uk/1/hi/7425078.stm [Accessed on 29 May 2008].
52. BBC News, 4 March 2008. Q&A: Rising World Food Prices. [Online]. Available at: http://news.bbc.co.uk/1/hi/7276971.stm [Accessed on 4 March 2008].
53. BBC News, 5 October 2006. Biofuels Will not Lead to Hunger. [Online]. Viewpoint by Peter Kendall. Available at: http://news.bbc.co.uk/1/hi/sci/tech/5406458.stm [Accessed on 24 January

2007].
54. BBC News, 7 July 2008. UK to Slow Expansion of Biofuels. [Online]. Available at: http://news.bbc.co.uk/1/hi/uk_politics/7493482.stm [Accessed on 7 July 2008].
55. BBC News, 7 September 2007. Salmond Rejects UK Nuclear Policy. [Online] Available at: http://news.bbc.co.uk/1/hi/scotland/south_of_scotland/6982308.stm [Accessed 7 September 2007].
56. BBC, 16 October 2008. The Cost of Food: Facts and Figures. [Online]. Available at: http://news.bbc.co.uk/1/hi/7284196.stm [Accessed on 16 October 2008].
57. BBC, 16 September 2008. Lehman Bros Files for Bankruptcy. [Online]. Available at: http://news.bbc.co.uk/1/hi/7615931.stm [Accessed on 16 September 2008].
58. BBC, 22 April 2008. Leaders Warn on Biofuels and Food. [Online]. Available at: http://news.bbc.co.uk/1/hi/world/americas/7359880.stm [Accessed on 22 April 2008].
59. Beck, U., 1992. Risk Society: Towards a New Modernity. London. Sage.
60. Beck, U., 1994. The Reinvention of Politics: Towards a Theory of Reflexive Modernisation. In Beck, U., Giddens, A. and Lash, S. ed. Reflexive Modernisation: Politics, Traditions and Aesthetics in the Modern Social Order. Polity Press: Cambridge, MA. pp.1-55.
61. Beck, U., 1998. Politics of Risk Society. In Franklin, J. ed. The Politics of Risk Society. Cambridge, Polity Press.
62. Beck, U., 2000. Risk Society Revisited. In Adam, B., Beck, U. and van Loon, J. eds., 2000. The Risk Society and Beyond. London. Sage.
63. Beddington, J., 2008. Food Security and Agriculture. [Online]. Available at: http://www.stwr.org/food-security-agriculture/food-crisis-will-take-hold-before-climate-change-warns-chief-scientist.html [Accessed on 6 March 2008].
64. Bell, J., 1993. Doing Your Research Project: A Guide for First Time Researcher in Education and Social Science. Open University Press, Milton Keynes.
65. Ben-Ner, A., Montias, J. M. Neuberger, E., 1993. Basic Issues in Organisations: A Comparative Perspective In Journal of Comparative Economics 17. pp. 207-242.
66. Bent, S., 2007. Renewable Energy: Conversion, Transmission and Storage. Elsevier.
67. Berger, P. L. and Luckman, T., 1966. The Social Construction of Reality. London: Penguin.
68. Better Sugarcane Initiative (BSI), 2008. About BSI. [Online]. Available at: http://www.bettersugarcane.org/ [Accessed on 5 January 2008].
69. Better Sugarcane Initiative (BSI), 2009. Code of Conduct for Members of the BSI. [Online]. Available at: http://www.bettersugarcane.org/governance.html#codeconduct [Accessed on 15 July 2009].

70. Better Sugarcane Initiative (BSI), 2010. Our Members. [Online]. Available at: http://www.bettersugarcane.org/corporate_social_responsibility.html [Accessed on 15 February 2010].
71. Bhattacharya, S., 1995. Domestic Petroleum Product Pricing Policy: Old Issues in New Perspective. Energy Sources, 17.
72. Bhattacharya, S., 2006. Managing Uncertainty Through Postponement. The ICFAI Journal of Operations Management, Vol. 5, No. 3, pp. 28-38. Postponement strategy on the supply chain performance.
73. Bhojvaid, P. P., 2006. Biofuels: Towards a Greener and Secure Energy Future. The Energy Research Institute.
74. Biodiesel Fuel Online, 2009. How Much Does It Cost To Produce Biodiesel? [Online]. Available at: http://www.biodieselfuelonline.com/How_Much_Does_It_Cost_To_Produce Biodiesel.html [Accessed on 27 May 2009].
75. Bioenergy and Energy Planning Research Group, 14 October 2009. Label for Sustainable Biofuels. Ecole Polytechnique Federale de Lausanne.
76. Biofuels Digest, 2009. About Us. [Online]. Available at: http://biofuelsdigest.com/bdigest/about-us/ [Accessed on 18 January 2009].
77. BiofuelsDigest, 11 September 2009. Brazilian Sugarcane. [Online]. Available at: http://www.biofuelsdigest.com/blog2/2009/09/11/brazilian-flex-fuel-cars-now-have-94-percent-market-share-for-new-sales-ethanol-at-65-percent discount-to-gasoline-cost/ [Accessed on 12 September 2009].
78. BiofuelWatch, 2009. About BiofuelWatch. [Online]. Available at: http://www.biofuelwatch.org.uk/aboutus.php [Accessed on 23 December 2009].
79. Biopact, 13 June 2007. Mendel and BP Collaborate on Grass Breeding for Cellulosic Biofuels. [Online]. Available at: http://news.mongabay.com/bioenergy/2007/06/mendel-and-bp-collaborate-on-grass.html [Accessed on 13 June 2007].
80. Biotechnology and Biological Sciences Research Council (BBSRC), 2009. Our Organisation. [Online]. Available at: http://www.bbsrc.ac.uk/organisation/organisation-index.aspx [Accessed on 22 February 2009].
81. Black, J., Hashimzade, N. and Myles, G., 2009. A Dictionary of Economics. Oxford University Press. [Online]. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t19.e3278 [Accessed on 4 July 2009].
82. Black, J., Hashimzade, N. and Myles, G., 2009a. A Dictionary of Economics. Oxford University Press. [Online]. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t19.e3223 [Accessed on 4 July 2009].
83. Black, J., Hashimzade, N. and Myles, G., 2009a. A Dictionary of Economics. Oxford University Press. [Online]. Available at:http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t19.e3943 [Accessed on 5 July 2009].
84. Black, J., Hashimzade, N. and Myles, G., 2009b. A Dictionary of Economics.

Oxford University Press. [Online]. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t19.e2715 [Accessed on 4 July 2009].
85. Black, J., Hashimzade, N. and Myles, G., 2009b. A Dictionary of Economics. Oxford University Press. [Online]. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t19.e1993 [Accessed on 5 July 2009].
86. Bockris, J. M., 2009. Renewable Energies: Feasibility, Time and Cost Options. Nova Science Publishers Inc.
87. Bohi, D. and Toman, M., 1996. The Economics of Energy Security, Boston, Kluwer Academic Publishers.
88. Booth, E., Booth, J., Cook, P., Ferguson, B and Walker, K., October 2005. Economic Evaluation of Biodiesel Production from Oilseed Rape grown in North and East Scotland. Scottish Agricultural College.
89. Boyle, G., 2004. Introductory Overview. In Boyle, G., Everett, B. and Ramage, J. 2004. Energy Systems and Sustainability. Oxford University Press. pp. 3-54. Ch.1.
90. Boyne, R., 2003. Risk. Open University Press.
91. BP, 1 April 2009. Sustainability Review 2008. Ernst & Young. BP Corporate Report.
92. BP, 11 August 2009. BP and Martek Biosciences Enter a Joint Development Agreement to Deliver Advanced Biodiesels. [Online]. Available at: http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7055476 [Accessed on 13 August 2009].
93. BP, 14 February 2008. DuPont and BP Disclose Advanced Biofuels Partnership Targeting Multiple Butanol Molecules. [Online]. Available at: http://www.bp.com/genericarticle.do?categoryId=4705&contentId=7041073 [Accessed on 12 March 2008].
94. BP, 19 April 2007. Biobutanol Performance Similar to Unleaded Gasoline, According to New Fuel Testing. [Online]. Available at: http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7032451 [Accessed on 12 May 2007].
95. BP, 2 February 2006. BP to Fund Indian Biofuel Production Study by the Energy and Resources Institute. [Online]. Available at: http://www.bp.com/genericarticle.docategoryId=2012968&contentId=7014607 [Accessed on 1 February 2007].
96. BP, 20 June 2006. BP and DuPont Announce Partnership to Develop Advanced Biofuels. [Online]. Available at: http://www.bp.com/genericarticle.docategoryId=2012968&contentId=7018942 [Accessed on 18 January 2007].
97. BP, 2006a. Biofuels Glossary. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9019294&contentId=7035040 [Accessed on 15 January 2007].
98. BP, 2006b. BP-DuPont Biofuels Fact Sheet. BP Publication.
99. BP, 2007a. Bringing on Biofuels. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9021004&contentId

=7038907 [Accessed on 1 January 2008].
100. BP, 2007b. BP, DuPont and ABF Partnership. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9027833&contentId=7050736 [Accessed on 3 June 2007].
101. BP, 2007c. Watch and Learn. [Online]. Available at: http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/complex_flash/bp_complex/bp_biofuels_animation_v7.swf [Accessed on 11 March 2007].
102. BP, 2008a. Biofuels. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9023629&contentId=7043839 [Accessed on 27 January 2008].
103. BP, 2008b. Breath of Fresh Air. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9025124&contentId=7046719 [Accessed on 23 November 2008].
104. BP, 2008c. Sweet Success. [Online] Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9024456&contentId=7045450 [Accessed on 2 July 2008].
105. BP, 2008d. Tropical BioEnergia. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9028360&contentId=7051663 [Accessed on 12 May 2008].
106. BP, 2008e. BP-DuPont Biofuels Fact Sheet. BP Publication.
107. BP, 2008f. Biofuels Feedstocks. [Online]. Available at: http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/complex_flash/bp_complex/MainMovie6.swf [Accessed on 14 February 2008].
108. BP, 2009a. Our Commitment to Biofuels. [Online] Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9027830&contentId=7050735 [Accessed on 22 May 2009].
109. BP, 2009b. Why Biofuels? [Online]. BP Corporate Report and Publications. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9030039&contentId=7055156 [Accessed on 1 September 2009].
110. BP, 2009c. Promoting a Sustainable Biofuels Industry. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9030055&contentId=7055191 [Accessed on 2 September 2009].
111. BP, 2009d. Tropical BioEnergia S.A. Joint Venture. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9028014&contentId=7051056 [Accessed on 16 April 2009].
112. BP, 2009e. BP and Biofuels. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9030043&contentId=7055171 [Accessed on 3 September 2009].
113. BP, 2009f. Biofuels Projects. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9030041&contentId=7055175 [Accessed on 13 September 2009].
114. BP, 2009g. Biofuels Technology. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9026132&contentId

=7048185 [Accessed on 21 March 2009].
115. BP, 2009h. Biobutanol: An Advanced Biofuels. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9027831&contentId=7050737 [Accessed on 5 February2009].
116. BP, 2009i. Producing Biofuels in the UK. [Online]. Available at:
117. BP, 2009j. Verenium Partnership. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9028015&contentId=7051055 [Accessed on 2 January 2009].
118. BP, 2009k. Developing Sustainable Biofuels. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9030054&contentId=7055190 [Accessed on 1 September 2009].
119. BP, 2009l. Biofuels and Sustainability. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9028347&contentId=7051580 [Accessed on 12 January 2009].
120. BP, 2009m. Getting Biofuels Right. [Online] http://www.bp.com/sectiongenericarticle.do?categoryId=9030042&contentId=7055187 [Accessed on 21 July 2009].
121. BP, 2009n. Biofuels Technology. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9030040&contentId=7055174 [Accessed on 12 September 2009].
122. BP, 2009o. What are the Issues? [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9030053&contentId=7055188 [Accessed on 3 September 2009].
123. BP, 2009p. Cellulosic Biofuels Fact Sheet. BP Publication.
124. BP, 2009q. Advanced Biofuels. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9030044&contentId=7055172 [Accessed on 5 August 2009].
125. BP, 2009r. Sugar to Diesel Fact Sheet. BP Corporate Report.
126. BP, 2010a. Exploration and Production. [Online]. Available at: http://www.bp.com/genericarticle.do?categoryId=11&contentId=2000425 [Accessed on 15 February 2010].
127. BP, 2010b. Refining and Marketing. [Online]. Available at: http://www.bp.com/genericarticle.do?categoryId=11&contentId=2000569 [Accessed on 15 February 2010].
128. BP, 2010c. BP Alternative Energy. [Online]. Available at: http://www.bp.com/genericarticle.do?categoryId=11&contentId=7045549 [Accessed on 15 February 2010].
129. BP, 2010d. BP in the United Kingdom. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=24&contentId=2000737 [Accessed on 12 August 2010].
130. BP, 24 April 2008. BP, Santelisa Vale and Maeda Unveil Plans to Invest R$1.66 Billion in Biofuels. [Online]. Available at: http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7043976 [Accessed on 12 May 2008].
131. BP, 29 July 2009. BP and Verenium Announce Vercipia Biofuels to Advance the Commercialisation of Cellulosic Ethanol. [Online]. Available at:

http://www.bp.com/genericarticle.do?categoryId=4705&contentId=7055225 [Accessed on 4 August 2009].
132. BP, 29 June 2007. BP and D1 Oils Form Joint Venture to Develop Jatropha Biodiesel Feedstock. [Online]. Available at: http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7034453 [Accessed on 2 August 2007].
133. BP, 30 October 2009. BP Biofuels Honoured. [Online]. Available at: http://www.bp.com/sectiongenericarticle.do?categoryId=9031576&contentId=7057864 [Accessed on 1 November 2009].
134. BP, 4 February 2010. The Challenge of Energy Security. Speech delivered by Tony Hayward, at London Business School.
135. BP, February 2007. BP Biofuels, A Growing Alternative. BP Corporate Report.
136. Brady, T., Tierney, M. and Williams, R., 1992. The Commodification of Industry Applications Software Industrial and Corporate Change. Vol. 1 No. 3 pp.489-514.
137. Brayer, S., 1982. Regulation and Its Reform. Cambridge, MA. Harvard University Press.
138. Brayer, S., 1993. Breaking the Vicious Cycle. Cambridge, MA. Harvard University Press.
139. Brazalian Sugarcane Industry Association (UNICA), 2009. About Us-Mission. [Online]. Available at: http://english.unica.com.br/quemSomos/texto/show.asp?txtCode={A888C6A1-9315-4050-B6B9-FC40D6320DF1} [Accessed on 3 January 2009].
140. Breakwell, G. M., 2007. The Psychology of Risk. Cambridge University Press, Cambridge, UK.
141. Breton, E. J. and Gold, R. J., 1987. Cultivating Invention. Research Technology Management. Issue September-October. pp. 9-12.
142. Broere, W., 15 February 2008. Harvesting Energy from Algae. Shell International B.V. The Netherlands.
143. Brown, L., 2008. Biofuels. [Online]. Earth Policy Institute. Available at: http://www.earth-policy.org/ [Accessed on 4 November 2008].
144. Bruijin, J. A. and ten Heuvelhof, E. F., 1999. Scientific Expertise in Complex Decision-Making Processes, Science and Public Policy. Vol. 26, no. 3, pp. 151-161.
145. Burgelman, R. A., Christensen, M. C., Wheelwright, S. C., 2004. Enactment of Technology Strategy: Developing a Firm's Innovate Capabilities. Strategic Management of Technology and Innovation, McGraw Hill. pp. 662-663.
146. Butler, R., 21 August 2007. Biofuels Driving Destruction of Brazilian Cerrado. [Online]. Mongabay.com. Available at: http://news.mongabay.com/2007/0821-cerrado.html [Accessed on 21 August 2007].
147. Calhoun, C., 2002a. Dictionary of the Social Sciences. [Online]. Oxford University Press. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t104.e1700 [Accessed on 5 July 2009].

148. Calhoun, C., 2002b. A Dictionary of Social Science. [Online]. Oxford University Press. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t104.e1031 [Accessed 5 July 2009].
149. Callon, M., 1992. The Dynamics of Techno-Economic Networks. In Coombs. R., Saviotti, P.P. and Walsh, V. (eds.) Technological Change and Company Strategy. Economic and Sociological Perspectives. London: Academic Press.
150. Callon, M., 1993. Variety and Irreversibility in Networks of Technique Conception and Adoption. In Foray, D and Freeman, C. eds., 1993. Technology and the Wealth of Nations: The Dynamics of Constructed Advantage London: Pinter. Chn. 11. pp. 232-268.
151. Campaign Against Climate Change, 2008. Biofuels Making the Climate Crisis Worse, Not Better. [Online]. Available at: http://www.campaigncc.org/biofuels.shtml [Accessed on 1 September 2008].
152. Campbell. C. J., 2005. Oil Crisis. Multi Science Publishing Co. Ltd.
153. Caspermeyer, J., 2 November 2007. ASU Launches Renewable Biofuel Research Initiative with BP and SFAz. [Online]. Available at: http://www.biodesign.asu.edu/news/asu-launches-renewable-biofuel-research-initiative-with-bp-and-sfaz [Accessed on 2 February 2008].
154. Catherine, S. and Stevenson, A., 2005. The Oxford Dictionary of English. [Online]. Oxford University Press. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t140.e53900 [Accessed 5 July 2009].
155. CBC News, 11 June 2009. Ottawa Station 1st in World to Sell Biofuels from Wheat Straw. [Online]. Available at: http://www.cbc.ca/canada/ottawa/story/2009/06/11/biofuel-shell-wheat-straw.html [Accessed on 11 June 2009].
156. Centre for Jatropha Promotion, 2008. About Jatropha Plant. [Online]. Available at: http://www.jatrophabiodiesel.org/aboutJatrophaPlant.php?_divid=menu1 [Accessed on 17 January 2008].
157. Chakrabortty, A., 3 July 2008. Secret Report: Biofuels Caused Food Crisis. [Online]. The Guardian. Available at: http://www.guardian.co.uk/environment/2008/jul/03/biofuels.renewableenergy [Accessed on 3 July 2008].
158. Chapman, R. J., 2006. Simple Tools and Techniques for Enterprise Risk Management. John Wiley & Sons.
159. Chazan, G., 19 October 2009. Big Oil Looks to Biofuels. [Online]. The Wall Street Journal, Business. Available at: http://online.wsj.com/article/SB10001424052970204731804574386960944758516.html [Accessed on 19 October 2009].
160. Chevron, 29 May 2007.Chevron and Texas A&M Form Strategic Biofuels Research Alliance. [Online]. Available at: http://www.chevron.com/news/press/Release/?id=2007-05-29b [Accessed on 10 June 2007].
161. Chevron, 31 October 2007. Chevron and National Renewable Energy

Laboratory to Collaborate on Research to Produce Transportation Fuels Using Algae. [Online]. Available at: http://www.chevron.com/news/press/release/?id=2007-10-31 [Accessed on 10 November 2007].
162. Choren Industries GmbH, 2008. Biomass to Energy. [Online]. Available at: http://www.choren.com/en/choren_industries/company/ [Accessed on 2 May 2008].
163. Choren, 2009a. Biomass to Energy, A Clean Business. [Online]. Available at: http://www.choren.com/en/biomass_to_energy/btl_production/ [Accessed on 23 July 2009].
164. Choren, 2009b. BTL made by Choren. [Online]. Available at: http://www.choren.com/en/energy_for_all/btl/ [Accessed on 23 July 2009].
165. Christiansen, C., R., 25 February 2009. Shell Awards Prize for Algae-to-Biodiesel Process. [Online]. Available at: http://www.biodieselmagazine.com/article.jsp?article_id=3264 [Accessed on 21 March 2009].
166. Clark, K. B., 1985. The Interaction of Design Hierarchies and Market Concepts in Technological Evolution. Research Policy 21. pp. 215-236.
167. Clark, P. and Staunton, N., 1989. Innovation in Technology and Organisation. London: Routledge.
168. Clemen, R. T., 1996. Making Hard Decisions: An Introduction to Decision Analysis. Belmont, CA: Duxbury Press.
169. Coase, R. H., 1937. The Nature of the Firm. In Gregory, P. R. and Stuart R. C., 2004. Definition and Classification of Economic Systems. In Comparing Economic Systems in the Twenty First Century. Houghton Mifflin Company. pp. 17-40. Ch. 2.
170. Codexis Inc, 2009. Company. Catalysing Clean Technology. [Online]. Available at: http://www.codexis.com/company [Accessed on 22 July 2009].
171. Colledge, R. G. and Stimpson, R. J., 1997. Spatial Behaviour: A Geographical Perspective. Guilford Press.
172. Collingridge, D., 1992. The Management of Scale: Big Organisations, Big Decisions, Big Mistakes London/NY: Routledge.
173. Collins, H. M., 1983. An Empirical Relativist Programme in the Sociology of Scientific Knowledge. In Knorr-Cetina, K.D. And Mulkay M. eds., *Science Observed: Perspectives on the Social Study of Science.* London: Sage.
174. Colman A. M. ed., 2009a. A Dictionary of Psychology. Oxford University Press. [Online]. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t87.e7242 [Accessed on 4 July 2009].
175. Colman A. M., 2009b. A Dictionary of Psychology. Oxford University Press. [Online]. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t87.e8659 [Accessed 4 July 2009].
176. Commission of the European Communities, 2000. Communication from the Commission on the Precautionary Principle. Brussels, Belgium: CEC.
177. Commission of the European Communities, 2005. Biomass Action Plan.

[Online]. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2005:0628:FIN:EN:PDF [Accessed on 12 July 2009].

178. Commission of the European Communities, 24 April 2009. The Renewable Energy Progress Report: Commission Report in accordance with Article 3 of Directive 2001/77/EC, Article 4(2) of Directive 2003/30/EC and on the implementation of the EU Biomass Action Plan, COM(2005)628. COM(2009) Final.

179. Commission of the European Communities, 7 November 2001. Promotion of the Use of Biofuels for Transport (DPB).COM (2001) 547.

180. Commission of the European Communities, 8 February 2006. An EU Strategy for Biofuels. COM (2006) 34 Final.

181. Comte, A., 1853. The Positive Philosophy of Auguste Comte (trans. H. Martineau) London: Trubner and Co. In Easterby-Smith, M., Thrope, R. and Lowe, A. 2004. *Management Research*. Sage Publication Ltd.

182. Cooper, D. F and Chapman, C., 1987. Risk Analysis for Large Projects: Models, Methods and Cases. John Wiley & Sons.

183. Cooper, D. R., Schindler, P. S., 2008. Business Research Methods. Irwin McGraw Hill.

184. Cosan S.A., 2010. Profile. [Online]. Available at: http://www.cosan.com.br/cosan2009/index_pti.html [Accessed on 16 February 2010].

185. Council for the Protection of Rural England, 1991. Evidence to the Dept of Energy's Renewable Energy Advisory Group, HMSO, London.

186. Countryside Council for Wales, 1992. Wind Turbine Power Stations, CCW Report, Bangor.

187. Courtney, H. Kirkland, J., and Viguerie, P., 1999. Strategy Under Uncertainty. In Harvard Business Review on Managing Uncertainty. Harvard Business School Press. pp. 1-32.

188. Cowan, R., 1992. High Technology and the Economics of Standardisation. In Dierkes, M and Hoffmann, U. eds., 1992. New Technology and the Outset: Social Forces in the Shaping of Technological Innovations Frankfurt/NY: Campus/Westview. Chn.14, pp. 279-300.

189. Cronberg, T., 1992. Technology in Social Sciences: The Seamless Theory. Mimeo, Technical University of Denmark, Lyngby, pp.20.

190. Crow, G., Wiles, R., Heath, S and Charles, V., 2004. Informed Consent and the Research Process: Following Rules or Striking Balances? Journal of Social Research Methodology. 6,4:357-360.

191. Culp, C. L., 2006. Structured Finance and Insurance: The ART of Managing Capital and Risk.John Wiley & Sons.

192. D1 Oil PLC, 2009a. Growing Energy Solutions. [Online]. Available at: http://www.d1plc.com/ [Accessed on 11 June 2009].

193. D1 Oil PLC, 2009b. D1-BP Fuel Crops Limited. [Online]. Available at: http://www.d1plc.com/agronomyFuel.php [Accessed on 12 June 2009].

194. Daintith, J., 2009. A Dictionary of Physics. [Online]. Oxford University Press. Available at:

http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t83.e442 [Accessed on 22 July 2009].
195. Dale, R. S., 1996. Risk and Regulation in Global Securities Markets. John Wiley & Sons.
196. David, P., 1975. Technical Choice, Innovation and Economic Growth: Essays on American and British Experience in the Nineteenth Century. Cambridge University Press.
197. DEFRA, June 2009. Adapting to Climate Change: The UK Climate Change Projects.
198. DeKay, M., Small, M.J., Fischbeck, P.S., Farrow, R.S., Cullen, A., Kadane, J.B., Lave, L.B., Morgan, M.G. and Takemura, K., 2009. Risk-Based Decision Analysis in Support of Precautionary Policies. In Loftstedt, R.E. and Boholm, A. eds., 2009. *Risk*. Earthscan. Ch.12. pp.221-247.
199. Demo Plant Fuel Production, [Online]. Available at: http://www.iogen.ca/ [Accessed on 11 January 2010].
200. Denney, D., 2005. Risk and Society. Sage Publication Ltd. Ch. 2. pp. 13-40.
201. Denzin, N. K., 1978. *T*he Research Act: A Theoretical Introduction to Sociological Methods. New York: McGraw-Hill.
202. Denzin, N. K., and Lincoln, Y. S., 2003. Collecting and Interpreting Qualitative Materials. California, United Stated of America: Sage Publications.
203. Department for Environment, Food and Rural Affairs (Defra), 2009. Agriculture in the United Kingdom 2008.
204. Department for Transport (DfT), 2003. Powering Future Vehicles Strategy. [Online]. Available at: http://www.dft.gov.uk/pgr/roads/environment/poweringfuturevehicles/poweringfuturevehiclesstrategy [Accessed on 12 February 2007].
205. Department for Transport (DfT), 2007. Low Carbon Transport Innovation Strategy. [Online]. Available at: http://www.dft.gov.uk/pgr/scienceresearch/technology/lctis/lowcarbontis?page=10 [Accessed on 12 July 2007].
206. Department for Transport (DfT), 2008. Government Support: Duty Incentive and RTFO Scheme Proposals. [Online]. Available at: http://www.dft.gov.uk/pgr/roads/environment/rtfo/governmentsupport [Accessed on 22 April 2008].
207. Department for Transport (DfT), 2009a. Sustainable Development-Protecting Environment. Annual Report and Resource Accounts 2009. [Online]. Available at: http://www.dft.gov.uk/about/publications/apr/ar2009/chapter6.pdf [Accessed on 11 October 2009]. Chapter 6.
208. Department for Transport (DfT), 2009b. Results from the Department for Transport's National Transport Model. [Online]. Available at: http://www.dft.gov.uk/pgr/economics/ntm/forecasts2009/pdf/forecasts2009.pdf [Accessed on 7 November 2009].
209. Department for Transport (DfT), 2010a. Aviation Environment Programme Board 10. [Online]. Available at:

http://www.dft.gov.uk/pgr/aviation/environmentalissues/programmeboard/minutes/pdf/aepb250110.pdf [Accessed on 21 July 2010].
210. Department for Transport (DfT), 2010b. Fact Sheet. UK Transport and Climate Change Data. [Online]. Available at: http://www.dft.gov.uk/pgr/statistics/datatablespublications/energyenvironment/climatechangefactsheets.pdf [Accessed on 8 August 2010].
211. Department of Energy and Climate Change, 2006. Climate Change the UK Programme.
212. Department of Energy, 1989. The Severn Barrage Project: General Report. Energy Paper 57, HMSO, London.
213. Dermirbas, A., 2008. Biofuels: Securing the Planet's Future Energy Needs. Springer.
214. Deutscher, H., 11 June 2009. Shell, Iogen announce cellulosic advancements. Biomass Magazine. Iogen Corporation. 2010.
215. Dinneen, B., 2007. Testimony before Committee on Senate Energy and Natural Resouces. In Easton, T. A. 2009. *Taking Sides: Clashing Views in Energy and Society.* McGraw-Hill Higher Education. pp. 322-329.
216. Doctor, N. R., Newton, D. P. and Pearson, A., 2000. Managing Uncertainty in Research and Development. In Technovation. 21(2). pp. 79-90.
217. Dorfman, M. S., 1997. Introduction to Risk Management and Insurance: Prentice Hall.
218. Dosi, G., 1988, Sources, Procedures and Microeconomic Effects of Innovations, Journal of Economic Literature, 26, pp. 1120-1171.
219. Doughlas, M., 1990. Risk as a Forensic Resource. Daedalus. Vol.119. No. 4. pp.1-16.
220. Doughlas, M., 1992. Risk and Culture: An Essay on the Selection of Technological and Environmental Dangers. University of California Press.
221. Doughlas, M., 1994. Risk and Blame. Routledge.
222. Doughlas, M., 2002. Purity and Danger: An Analysis of Concepts of Pollution and Taboo. Routledge.
223. Drapcho, C., Nghiem, J and Walker, T., 2008. Biofuels Engineering Process Technology. McGraw-Hill Professional.
224. Dryer, F., 11 August 2009. How Aviation Can Clean Up Its Act. [Online]. BBC News. Available at: http://news.bbc.co.uk/1/hi/sci/tech/8193125.stm [Accessed on 11 August 2009].
225. Dryzek, J., 1990. Discursive Democracy. Politics, Policies and Science. Cambridge University Press.
226. Easterby-Smith, M., Thrope, R. and Lowe, A., 2004. Management Research. Sage Publication Ltd.
227. Ecole Polytechnique Federae De Lasanne (EPFL), 2008. The Roundtable on Sustainable Biofuels. [Online]. Available at: http://cgse.epfl.ch/page65660.html [Accessed on 16 February 2008].
228. Eden, R., Posner, M., Bending, R. Crouch, E. and Stainslaw, J., 1983. Energy Economics: Growth, Resources and Policies. Cambridge University Press. pp. 1-25.
229. Edinburgh Napier University, 11 December 2007. Napier Launches the UK's

First Biofuel Research Centre of its Kind. [Online] Available at: http://www.news.napier.ac.uk/press/articles/article_10447.htm [Accessed on 1 January 2008].
230. Elky, S., 2006. An Introduction to Information System Risk Management. SANS Institute InfoSec Reading Room.
231. Elliott, D., 1995. The UK Wave Energy Programme. Technology Policy Group Occasional Paper 27, Open University, Milton Keynes.
232. Elliott, D., 2003a. Sustainability and Environmental Impact of Renewable Energy Sources. Royal Society of Chemistry.
233. Elliott, D., 2003b. Sustainable Energy: Choices, Problems and Opportunities. In Elliott, D. 2003. Sustainability and Environmental Impact of Renewable Energy Sources. Royal Society of Chemistry. Ch. 2. pp. 37-39.
234. Elliott, D., 2003c. Energy, Society and Environment: Technology for A Sustainable Future. Routledge. 2nd ed.
235. Elliott, D., 2003d. Getting Started: Institutional Obstacles. In Elliott, D., 2003. Energy, Society and Environment: Technology for A Sustainable Future. Routledge. pp. 191-204. Ch. 10.
236. Elliott, D., 2003e. Keeping Going: Deployment Problems. In Elliott, D., 2003. Energy, Society and Environment: Technology for A Sustainable Future. Routledge. pp. 205-218. Ch. 11.
237. Elliott, D., 2003f. Case Study: Public Reactions to Wind Farms in the UK. In Elliott, D., 2003c. Energy, Society and Environment: Technology for A Sustainable Future. Routledge. pp. 219-234. Ch. 12.
238. Elliott, D., 2007a. Nuclear or Not?: Does Nuclear Power Have a Place in a Sustainable Energy Future? Palgrave Macmillan.
239. Elliott, D., 2007b. Sustainable Energy: Opportunities and Limitations. Palgrave Macmillan.
240. Elliott, D., 2003. Getting Started: Institutional Obstacles. In Elliott, D., 2003. *Energy, Society and Environment: Technology for A Sustainable Future.* Routledge. pp. 191-204. Ch. 10.
241. Encyclopedia Britannica, 2008. Bagasse. [Online]. Available at: http://www.britannica.com/EBchecked/topic/48728/bagasse [Accessed on 12 June 2008].
242. Energy Biosciences Institute (EBI), 2008. EBI at a Glance. [Online]. Available at: http://www.energybiosciencesinstitute.org/index.php [Accessed on 12 March 2008].
243. Energy Technology Support Unit (ETSU), 1991a. Cost Modelling of Hot Dry Rock Systems. Volume 1: Main Report. Volume 2: Drilling Costs. Department of Energy, London.
244. Energy Technology Support Unit (ETSU), 1991b. Conceptual Design Study for a Hot Dry Rock Geothermal Energy Project, Summary RTZ Study. Department of Energy, London.
245. Energy Technology Support Unit, 1982. Strategic Review of Renewable Energy Technologies. Vol.1, ETSU Report R13, Harwell.
246. EPFL Energy Centre, 2009. Version One of the Principles and Criteria. [Online]. Available at: http://cgse.epfl.ch/page84341.html [Accessed on 1

December 2009].
247. Ericson, R. V. and Doyle, A., 2003. Risk and Morality. University of Toronto Press.
248. Europe Publications Office, 4 January 2007. Kyoto Protocol on Climate Change. [Online]. Available at: http://europa.eu/legislation_summaries/environment/tackling_climate_change/l28060_en.htm [Accessed on 15 January 2007].
249. European Automobile Manufacturers' Association, 2008. Setting National Fuel Quality Standards: Proposed Management of Diesel/Biodiesel Blends.
250. European Biodiesel Board, 2009. About EBB. [Online]. Available at: http://www.ebb-eu.org/index.php [Accessed on 22 December 2009].
251. European Biodiesel Board, 2009. Home. [Online]. Available at: http://www.ebb-eu.org/index.php [Accessed on 8 May 2009].
252. European Bioethanol Fuel Association, 2009. What We Do. [Online]. Available at: http://www.ebio.org/what.php [Accessed on 23 December 2009].
253. European Commission Energy and Transport Directorate, April 2006. Review of EU Biofuels directive. Public Consultation Exercise.
254. European Commission, January 2006. The European Climate Change Programme.
255. European Committee of Standardisation, 2009. About Us. [Online]. Available at: http://www.cen.eu/cenorm/aboutus/index.asp [Accessed on 14 April 2009].
256. European Environment Agency, (2008). Curbing CO_2 Emissions from Road Transport. [Online]. Available at: http://www.eea.europa.eu/themes/transport/multimedia/curbing-co2-emissions-from-road-transport/view [Accessed on 12 March 2008].
257. European Environment Agency's Scientific Advisory Body, 2008. 10 Percent Biofuels Target. [Online]. Available at: http://www.eea.europa.eu/highlights/suspend-10-percent-biofuels-target-says-eeasscientific-advisory-body [Accessed on 17 April 2008].
258. European Parliament and the Council of the European Union, 3 March 2003. Amending Directive 98/70/EC Relating to the Quality of Petrol and Diesel Fuels. 2003/17/EC.
259. European Union, 2003. EU Biofuels Directive: Directive on the Promotion of the Use of Biofuels and Other Renewable Fuels for Transport. 2003/30/EC.
260. European Union, 2009. EU Renewable Energy Directive: Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC. 2009/28/EC.
261. European Union, 2009. Fuel Quality Directive: Regards the Specification of Petrol, Diesel and Gas-oil, and Introducing a Mechanism to Monitor and Reduce Greenhouse Gas Emissions. 2009/30/EC.
262. Evan, J., 2008. GM Crops and Biofuels. [Online]. Available at: http://www.ethanolproducer.com/article.jsp?article_id=4462 [Accessed on 7 September 2008].
263. Evan, W. M. and Manion, M., 2002. Minding the Machines: Preventing Technological Disasters. Prentice Hall.
264. ExxonMobil, 14 July 2009. Algae Biofuels. [Online]. Available at:

http://www.exxonmobil.com/Corporate/energy_climate_con_vehicle_algae.aspx [Accessed on 15 July 2009].

265. FAO, 2009. Wheat. [Online]. Available at: http://www.fao.org/docrep/011/ai482e/ai482e03.htm [Accessed on 14 July 2009].

266. Feeds Marketing, 2010. Technical Information of Distillers' Malt Draff. [Online]. Available at: http://www.bocmpauls.co.uk/common/uploaded_files/53876965/4700005_53876965_Distillers%20Malt%20Draff.pdf [Accessed on 17 August 2010].

267. Financial Times, 1 February 2010. Shell Makes Good in Biofuels Promises. [Online]. Available at: http://www.ft.com/cms/s/0/9115c9f6-0f76-11df-a450-00144feabdc0.html [Accessed on 16 February 2010].

268. Fine, J. C., 18 July 2010. Algae Pollution a Worldwide Problem Affecting Marine Life. [Online]. Available at: http://www.theepochtimes.com/n2/content/view/38228/99999999/1/1/ [Accessed on 18 July 2010].

269. Fischer, F., 2004. Citizens and Experts in Risk Assessment: Technology Knowledge in Practical Deliberation. Technikfolgenabschatzung. 2,13. pp.90-98.

270. Fisher, C., 2004. Researching and Writing a Dissertation for Business Students. Harlow: Pearson.

271. Fishkin, J., 1995. The Voice of the People: Public Opinion and Democracy. New Haven: Yale University Press.

272. Flanagan, R. and Norman, G., 1993. Risk Management and Construction: Blackwell.

273. Fleck, J., 1993. Configurations: Crystallising Contingency. International Journal of Human Factors in Manufacturing. Vol. 3, No. 1, pp.15-36.

274. Flinn Foundation, 2 November 2007. SFAz Grant to Fund ASU-BP Biofuel Project. [Online]. Arizona Bioscience News. Available at: http://www.flinn.org/news/774 [Accessed 25 January 2008].

275. Flynn, R. 2007. Risk and the Public Acceptance of New Technologies. In Flynn, R. and Bellaby, P., eds., 2007. Risk and the Public Acceptance of New Technologies. Palgrave Macmillan. pp. 1-23.

276. Food and Agriculture Organisation (FAO) of the United Nations, 2008. Climate Change, Biofuels and Land.

277. Food and Agriculture Organisation (FAO), June 2009. Wheat. [Online]. Available at: http://www.fao.org/docrep/011/ai482e/ai482e03.htm [Accessed on 5 July 2009].

278. Fortune Global 500, [Online]. Available at: http://money.cnn.com/magazines/fortune/global500/2010/full_list/ [Accessed on 9 August 2010].

279. Freeman, C., 1992. The Economics of Hope. Essay on Technical Change, Economic Growth and the Environment. London: Pinter Publications.

280. Fried, E. R. and Trezise, P. H., 1993. Oil Security: Retrospect and Prospect, Washington, DC, The Brooking Institution.

281. Fuglestvedt, J., Berntsen, T., Myhre, G., Rypdal, K. and Skeie, R. B., 15

January 2008. Climate Forcing from the Transport. Proceedings of the National Academy of Sciences (PNAS) vol. 105 no. 2 pp. 454-458.
282. Funtowicz, S. O. and Ravetz, J. R., 1992. Three types of risk assessment and the emergence of post-normal science. In Krimsky, S. and Golding, D. eds., Social Theories of Risk, Praeger, Westport and London, pp. 251-273.
283. Gallagher, E., 2008. The Gallagher Review of the Indirect Effects of Biofuels Production. [Online]. Renewable Fuels Agency. Available at: http://www.unido.org/fileadmin/user_media/UNIDO_Header_Site/Subsites/Green_Industry_Asia_Conference__Maanila_/GC13/Gallagher_Report.pdf [Accessed on 29 November 2008].
284. Garud, R. and Ahlstrom, D., 1997. Technology Assessment: A Socio-Cognitive Perspective. Journal of Engineering and Technology Management 14. pp. 25-48.
285. Genus, A., 1993. The Political Construction and Control of Technology: Wave Power Renewable Energy Technologies. Technology Analysis and Strategic Management, 5(2). pp. 137-149.
286. George, F. L., Weber, E. U., Hsee, C. K. and Welch, N., 2009. Risk as Feelings. In Lofstedt, R. E. and Boholm, A. ed., 2007. Risk. Earthscan. pp. 113-152, Ch. 7.
287. Georgia Institute of Technology, 3 July 2006. Chevron Forms Research Partnership with Tech. [Online]. Available at: http://www.whistle.gatech.edu/archives/06/jul/03/chevron_sei.shtml [Accessed on 14 August 2006].
288. Gevo, 2009. The Road to Energy Independence. [Online]. Available at: http://www.gevo.com/about.php [Accessed on 27 April 2009].
289. Ghauri, P. N., Gronhaug, K. and Kristianslund, I., 1995. Research Methods in Business Studies. Prentice Hall.
290. Giddens, A., 1991. Modernity and Self-Identity. Cambridge: Polity Press.
291. Girardet, H and Mendonca, M., 2009. A Renewable World: Energy, Ecology and Equality-A Report for the World Future Council (WFC). Green Books.
292. Goldemberg, J., 2008. The Brazilian Biofuels Industry. Journal of Biotechnology for Biofuels. Volume 1: Issue 6.
293. Goodwin, P. and Wright, G., 2004. Decision Analysis for Management Judgement, Wiley, London, UK.
294. Graham, J. D. and Wiener, J. B., 1995. Risk vs Risk. Havard University Press Cambridge, MA.
295. Green, J., 1997. Risk and Misfortune: A Social Construction of Accidents. Routledge.
296. Gregory, P. R. and Stuart R. C., 2004. Definition and Classification of Economic Systems. In *Comparing Economic Systems in the Twenty First Century*. Houghton Mifflin Company. pp.17-40. Ch. 2.
297. Grimvall, G., Holmgren, A., Jacobsson, P., Thedeen, T., 2009. Risks in Technological System. Springer.
298. Guardian, 1 February 2010. Shell to Do Ddeal with Brazilian Biofuel Producer Cosan to Secure Future. [Online]. Available at: http://www.guardian.co.uk/business/2010/feb/01/shell-cosan-brazil-biofuel-

deal [Accessed on 16 February 2010].
299. Hammond, J., Keeney, R. and Raiffa, H., 1999. Smart Choices: A Practical Guide to Making Better Decisions. Harvard Business School Press, Cambridge, MA.
300. Hance, B. J., Chess, C. and Sandman, P. M., 1988. Improving Dialogue with Communities: A Risk Communication Manual for Government. Environmental Communication Research Program, Rutgers University, New Brunswick, NJ.
301. Hansson, O. S., 2009. A Philosophical Perspective on Risk. In Loftstedt, R.E. and Boholm, A. eds., 2009. Risk. Earthscan. Ch.3. pp. 43-52.
302. Hard, M., 1993. Beyond Harmony and Consensus: A Social Conflict Approach to Technology. Science, Technology & Human Values Vol. 18, No. 4 (Autumn), pp.408-432.
303. Harper, M., 1994. Wind Energy Still Blowing Strong, Safe Energy, 99, February/ March: 13.
304. Hawkins, K. and Thomas, J., 1984. Enforcing Regulation. Boston.
305. Hayek, F. A., 1994. The Road to Serfdom, University Of Chicago Press.
306. Helm, D., Kay, J., Thompson, D., 2000. Energy Policy and the Role of State in the Market for Energy. In Stevens, P. ed., 2000. The Economics of Energy Volume II. Edward Elgar Publishing Ltd. pp.413-433. Ch. 21.
307. Hennessy, P., 1990. Whitehall, London. Fontana Press.
308. Hertz, D. B and Thomas, H., 1983. Introduction: The Book, Issues, Definitions and Scope. In Risk Analysis and Its Applications. John Wiley & Sons. pp. 1-7.
309. Hester, R. E. and Harrison, R. M. eds., 2006. Chemicals in the Environment: Assessing and Managing Risk. Royal Society of Chemistry.
310. Hicks, J. R., 1932. The Theory of Wages. Macmillan. In Sijm, J.O.M. 2004. *Induced Technological Change and Spillovers in Climate Change Policy Modeling. An Assessment*. The Energy Research Centre of the Netherlands (ECN).
311. Hill, C. W. L., 2002. Entry Strategy and Strategic Alliances. In International Business Competing in the Global Marketplace. McGraw-Hill. pp. 440-441. Ch. 14.
312. Hirsch, T., 8 March 2007. Brazilian Biofuels' Pulling Power. [Online]. BBC News. Available at: http://news.bbc.co.uk/1/hi/sci/tech/6430563.stm [Accessed on 8 March 2007].
313. HMSO, 1988. The Tolerability of Risk from Nuclear Power Stations, Health and Safety Executive, Her Majesty's Stationery Office, London, UK.
314. Hood, C., Rothstein, H. and Baldwin, R., 2001. The Government of Risk: Understanding Risk Regulation Regimes. Oxford University Press.
315. Hood, C., Rothstein, H. and Baldwin, R., 2004a. Why Are Risk Regulation Regimes? Why Do They Matter? In The Government of Risk: Understanding Risk Regulation Regimes. Oxford University Press. Ch. 1. pp. 3-19.
316. Hood, C., Rothstein, H. and Baldwin, R., 2004b. The Comparative Anatomy of Risk Regulation Regimes. In The Government of Risk: Understanding Risk Regulation Regimes. Oxford University Press. Ch. 2. pp. 20-35.

317. Hood, C., Rothstein, H. and Baldwin, R., 2004c. How Far Does Context Shape Content in Risk Regulation Regimes?. In The Government of Risk: Understanding Risk Regulation Regimes. Oxford University Press. Ch. 4. pp. 62-69.
318. House of Commons Environmental Audit Committee, 2008. Are Biofuels Sustainable? The Government Response.
319. HR BioPetroleum, 2009. Company Overview. [Online]. Available at: http://www.hrbp.com/AboutUs/CompOvw.html [Accessed on 24 July 2009].
320. HSE (Health and Safety Executive), 2001. Reducing Risk- Protecting People, Health and Safety Executive. London.
321. Institution of Civil Engineers, 1998. Risk Analysis and Management of Project. Faculty of Actuaries, Institute of Actuaries.
322. Interesting Energy Facts. 25 March 2008. Biokerosene to be Used in Aviation. [Online]. Available at: http://interestingenergyfacts.blogspot.com/2008/03/biokerosene-to-be-used-in-aviation.html [Accessed on 25 March 2008].
323. International Union for Conservation of Nature, 2009. About IUCN. [Online]. Available at: http://www.iucn.org/about/ [Accessed on 11 September 2009].
324. Iogen Corporation, 2009. About Iogen. [Online]. Available at: http://www.iogen.ca/company/about/index.html [Accessed on 17 July 2009].
325. IRGC (International Risk Governance Council), 2005. Risk Governance-Towards an Integrative Approach, White Paper no 1, O. Renn with an Annex by P. Graham, IRGC, Geneva, Switzerland.
326. Jaeger, C. C., Renn, O., Rosa, E. A. and Webler, T., 2001. Risk, Uncertainty and Rational Action. Earthscan, London.
327. Jankowicz, D., 1991. Business Research Projects for Students. Thomson Learning.
328. Johnson, R. S. and Runge, F. C., 2007. Ethanol: Train Wreck Ahead? In Easton, T. A. 2009. Taking Sides: Clashing Views in Energy and Society. McGraw-Hill Higher Education. pp. 330-339.
329. Jourdan, C. and Michaelson, C., 2010. Extending Enterprise Risk Management to Address Emerging Risk. Pricewaterhousecoppers. Journal of Ambient Energy, 4(4). pp. 199-211.
330. Kagolo, F., 30 January 2010. Hunger Looms as Farmers Abandon Food Crops for Biofuel Crops in Uganda. [Online]. Available at: http://www.africanagricultureblog.com/2010/01/hunger-looms-as-farmers-abandon-food.html [Accessed on 1 February 2010].
331. Kaltschmitt, M., Streicher, W. and Wiese, A., 2007. Renewable Energy: Technology, Economics and Environment. Springer.
332. Kasperson, J. X. and Kasperson, R. E. ed., 2005. The Social Contours of Risk: Public, Risk Communication and the Social Amplification of Risk. Volume I. Earthscan Ltd.
333. Kasperson, J. X. and Kasperson, R. E. ed., 2005. The Social Contours of Risk: Risk Analysis, Corporations and the Globalization of Risk. Volume II. Earthscan Ltd.
334. Kasperson, R. E., 2005. Acceptability of human risk. In Kasperson J. X. and

Kasperson R. E. eds., *The Social Contours of Risk: Risk Analysis, Corporations and the Globalization of Risk.* Volume II. Earthscan, London, pp. 19-28.
335. Keeney, R. L., 1982. Decision Analysis: An Overview, Operations Research 39, 803-38.
336. Keeney, R. L., 1992. Value Focused Thinking. A Path to Guide Thinking and Analysis Regarding Climate Change Policies. Risk Analysis. Vol 6. pp. 989-1000.
337. Kemp, R., Olsthoorn, A., Oosterhuis, F.H. and Verbruggen, H., 1991. An Economic Analysis of Cleaner Technology: Theory and Evidence. In Proceedings of the Greening of Industry Conference, Noordwijk aan Zee, 17-19 November 1991.
338. King, D., 2008. Biofuels Energy. [Online]. Available at: http://www.guardian.co.uk/environment/2008/mar/25/biofuels.energy [Accessed on 1 April 2008].
339. King, J., 2008. The King Review of Low-Carbon Cars. Part II: Recommendation for Action.
340. Kirk, J. and Miller, M. L., 1986. Reliability and Validity in Qualitative Research. Beverley Hills. Sage.
341. Klinke, A. and Renn, O., 2002. A New Approach to Risk Evaluation and Management: Risk-Based, Precaution-Based and Discourse-Based Strategies. Risk Analysis, vol. 22, no. 6, pp. 1071-1094.
342. Knight, F., 1921. Risk, Uncertainty and Profit. New York. Hart, Schaffner and Marx. In Holton, G. A. 2004. Defining Risk. Journal of Financial Analysts. Volume 60. Number 6.
343. Knott, T., April 2007. Back to A Bio Future. BP Corporate Report.
344. Kolmar, P., 2009. Country Report: Brazil. BP Magazine. Issue 1. BP Publication.
345. Korath, L. F., 1998. Auditing Concepts and Applications: A Risk Analysis Approach. South-Western, Division of Thomson Learning.
346. Krauss, C., 26 May 2009. Big Oil Warms to Ethanol and Biofuels Companies. [Online]. The New York Times. Available at: http://www.nytimes.com/2009/05/27/business/energy-environment/27biofuels.html [Accessed on 28 May 2009].
347. Krechowicz, D. and Fernando, H., 2009. Emerging Risk. Impacts of Key Environmental Trends in Emerging Asia. Report from World Resources Institute and International Finance Corporation. World Bank Group.
348. Lal, R. and Stewart, B.A., 2009. Carbon Management, Biofuels an Soil Quality. CRC Press.
349. LaMonica, M., 22 September 2008. BP Scientist: To Cut Oil Use, Make Carbon Expensive. cnet news. [Online]. Available at: http://news.cnet.com/8301-11128_3-10047746-54.html [Accessed on 22 September 2008].
350. Langeveld, H., Meeusen, M. and Sanders, J., 2009. The Biobased Economy: Biofuels, Materials and Chemicals in the Post Oil Era.
351. Langley, A., 1999. Strategies for Theoritising from Process Data. *Academy of*

Management Review, 24(4), 691-710.
352. Latin and South American Network, 2007. Declaration on Biofuels. [Online]. Available at: http://www.wrm.org.uy/subjects/biofuels/EU_declaration.html [Accessed on 7 May 2007].
353. Latour, B., 1988. How to Write “The Prince” for Machines as well as Machinations. In Elliott, B. (ed.) 1988. Technology and Social Process. Edinburgh University Press. pp. 20-43.
354. Laudan, L., 1996. The Pseudo-Science of Science? The Demise of the Demarcation Problem, In Laudan, L. ed., Beyond Positivism and Relativism: Theory, Method and Evidence. Westview Press, Boulder, CO. pp. 166-192.
355. Law, E. J., 2009. A Dictionary of Business and Management. [Online]. Oxford University Press. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t18.e6170 [Accessed on 1 January 2010].
356. Law, E. J., 2009. A Dictionary of Business and Management. [Online]. Oxford University Press. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t18.e6524 [Accessed on 5 July 2009].
357. Law, E. J. and Smullen, J., 2008. A Dictionary of Finance and Banking. [Online]. Oxford University Press. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t20.e5710 [Accessed on 5 July 2009].
358. Law, J. and Owe, G., 1999. Dictionary of Accounting. Oxford University Press. [Online]. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t17.e3369 [Accessed on 5 July 2009].
359. Leedy, P. D., 1989. Practical Research-Planning and Design. Macmillan Publishing Company, New York.
360. Leiby, P.N., Bowman, D. and Jones, D.W., 2002. Improving Energy Security through an International Cooperative Approach to Emergency Oil Stockpilling, Oak Ridge National Laboratory Web Site.
361. Leiss, W., 1996. Three Phases in Risk Communication Practice. In Kunreuther, H. and Slovic, P. eds., Annals of the American Academy of Political and Social Science, Special Issue: Challenges in Risk Assessment and Risk Management, Sage, Thousand Oaks, CA, pp. 85-94.
362. Leiss, W. and Chociolko, C., 1994. Risk and Responsibilities. McGill-Queen's University Press.
363. Lewis, J. and Ritchie, J., 2003. Generalising from Qualitative Research. In Ritchie, J. and Lewis, J. (eds.) *Qualitative Research Practice: A Guide for Social Science Students and Researchers*. London: Sage Publications Limited.
364. Lindley, D. V., 1971. Making Decisions, John Wiley, London.
365. Link Directorate, November 2000. OST General Guidance on Link Collaboration Agreement. Office of Science and Technology.
366. Logan, C., 2007. Getting Greener: The Net Generation of Biofuels. Corporate Report. Shell International B.V.

367. Low Carbon Vehicle Partnership, 2009. About LowCVP. [Online]. Available at: http://www.lowcvp.org.uk/about-lowcvp/index.asp [Accessed on 14 April 2009].
368. Low Carbon Vehicle Partnership, January 2005. Biofuels for Road Transport. [Online]. Available at: http://www.lowcvp.org.uk/assets/viewpoints/Biofuels%20for%20Road%20Transport%20(Jan05).pdf [Accessed on 7 April 2007].
369. Luciani, G. and Salustri, M., 1998. Vertical Integration as a Strategy for Oil Security. In Stevens, P.J. 1998. Strategic Positioning in the Oil Industry: Trends and Options, Abu Dhabi, The Emirates Centre for Strategic Studies and Research.
370. Luhmann, N., 1991. Risk: A Sociological Theory.
371. Lundgren, R. E., 1994. Risk Communication: A Handbook for Communicating Environmental, Safety and Health Risks, Battelle Press, Columbus Ohio.
372. Lundgren, R. E. and McMakin, A. H., 2008. Risk Communication: A Handbook for Communicating Environmental, Safety and Health Risks. Wiley-Blackwell.
373. Lundvall, B.A., 1988. Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation. In Dosi, G., Nelson, R., Silverberg, G. and Soete, L. eds., Technical Change and Economic Theory. London: Pinter.
374. Lundvall, B.A., 1993. User-Producer Relationships, National Systems of Innovation and Internationalisation. In Foray, D and Freeman, C. (eds.) 1993 Technology and the Wealth of Nations: The Dynamics of Constructed Advantage London: Pinter. pp. 277-301.
375. Lupton, D., 1999. Risk. Routledge.
376. Lupton, D., 2000. Risk and Sociocultural Theory: New Directions and Perspectives. Cambridge University Press.
377. MacKenzie, D. and Wajcman, J., (eds.) 1985. The Social Shaping of Technology: How the Refrigerator Got Its Hum. Milton Keynes, Open University Press.
378. MacKerron, G. and Pearson P., 1996. The International Energy Experience, London, Imperial College Press.
379. MacKerron, G. and Pearson P., 2000. The UK Energy Experience: A Model or a Warning?, London, Imperial College Press.
380. MacLean, D., 1986. Social Values and the Distribution of Risk. In MacLean, D. ed., Values at Risk. Rowman and Allanheld, Totowa, NJ, pp. 75-93.
381. Mallesons S. J., 2002. Memorandum of Understanding. Corporate Report.
382. Mallon, K., 2006. Renewable Energy Policy and Politics: A Guide for Decision-Making. Earthscan.
383. Martek Biosciences Corporation, 2009. About Martek. [Online]. Available at: http://www.martek.com/about.aspx [Accessed on 15 August 2009].
384. Mathiason, N., 1 February 2010. Shell to do Deal with Brazilian Biofuels Producer Cosan to Secure Future. [Online]. The Guardian. Available at: http://www.guardian.co.uk/business/2010/feb/01/shell-cosan-brazil-biofuel-

deal [Accessed on 1 February 2010].
385. Maynard, R., 1 March 2007. Biofuels Report: Against the Grain. [Online]. The Ecologist. Available at: http://www.theecologist.org/investigations/energy/269091/biofuels_report_against_the_grain.html [Accessed on 1 March 2007].
386. McBrewster, J., Miller P. F. and Vandome A. F., 2009. Algae Fuel. Alphascript Publishing.
387. Mclean, E.I. And McMillan, A., 2009. The Concise Oxford Dictionary of Politics. Oxford University Press 2009. [Online]. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t86.e1172 [Accessed on 4 July 2009].
388. McNeil, A. J., Frey, R. and Embrechts, P., 2005. Quantitative Risk Management: Concepts, Techniques, and Tools. Princeton University Press.
389. Mendel Biotechnology, 1 May 2009. Annual Report 2008.
390. Mendel., 2008. Our Mission. [Online]. Available at: http://www.mendelbio.com/aboutus/index.php [Accessed on 15 March 2008].
391. Michel, H., 2008. Rethink Biofuels. Says Noble Laureate. [Online]. http://newsinfo.inquirer.net/inquirerheadlines/nation/view/20080114-112152/Rethink-biofuel-says-Nobel-laureate [Accessed on 2 February 2008].
392. Michel, L., 2008. We Are Generous, But Not Naïve. [Online]. Available at: http://www.ipsnews.net/news.asp?idnews=40762 [Accessed on 14 March 2008].
393. Miles, M. B. and Huberman, A. M., 1994. An Expanded Sourcebook: Qualitative Data Analysis. California, United States of America: Sage Publications, Inc.
394. Mitchell, D., 2008. A Note on Rising Food Prices. [Online]. The World Bank Development Prospect Group. Available at: http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2008/07/28/000020439_20080728103002/Rendered/PDF/WP4682.pdf [Accessed on 27 January 2010].
395. Mitchell, D., 8 April 2008. A Note on Rising Food Prices. Unpublished Note [Online]. Available at: http://image.guardian.co.uk/sys-files/Environment/documents/2008/07/10/Biofuels.PDF [Accessed on 12 October 2009].
396. Mitchell, J.V., 1994. An Oil Agenda for Europe, London, Royal Institute for International Affairs.
397. Mitchell, J.V., Beck, P. and Grubb, M., 1996. The New Geopolitics of Energy, London, Royal Institute of International Affairs.
398. Mittelbach, M. and Gangl, S., 2001. Long Storage Stability of Biodiesel Made from Rapeseed and Used Frying Oil. In Journal of the American Oil Chemists' Society 78(6) pp. 573.
399. Moles, P. and Terry, N., 1997. The Handbook of International Financial Terms. Oxford University Press. [Online]. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t181.e6396 [Accessed 4 July 2009].
400. Moles, P. and Terry, N., 1997. The Handbook of International Financial

Terms. Oxford University Press. [Online]. Available at:http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t181.e8049 [Accessed 4 on July 2009].
401. Mollman, S., 23 August 2009. Green Goo Biofuels Gets a Boost. [Online]. CNN.com/technology. Available at: http://edition.cnn.com/2009/TECH/science/08/21/eco.algaebiofuel/index.html [Accessed on 31 August 2009].
402. Montias, J. M., 1976. The Structure of Economics Systems. New Haven, Yale University Press.
403. Moore, J., 26 September 1980. At the opening of the Southampton wave test tank, UK Department of Energy Press Release.
404. Moore, K. M., 1999. Risk Arbitrage: An Institutional Investor's Guide. John Wiley & Sons.
405. Morgan, M. G., 1990. Choosing and Managing Technology-Induced Risk. In Gickman, T. S. and Gough, M. eds., Readings in Risks, Resources for the Future, Washington, D.C. pp.17-28.
406. Morgan, M. G., 1995. Risk analysis: A personal assessment of the state of the field, Distinguished Contribution Award's Keynote Address, Society for Risk Analysis Annual Meeting, Honolulu, 3-6 December.
407. Morgan, M. G., Fischhoff, B., Bostrom, A., and Atman, C., 2001. Risk Communication: A Mental Models Approach. Cambridge University Press.
408. Morgan, M. G., Fischhoff, B., Bostrom, A., Lave, L. and Atman, C., 1992. Communicating Risk to the Public, Environmental Science and Technology, vol. 26, no. 11, pp. 2049-2056.
409. Nag, A., 2008. Biofuels Refining and Performance. McGraw-Hill Professional.
410. NAO, 1994. The Renewable Energy Research, Development and Demonstration Programme. National Audit Office, London.
411. National Renewable Energy Laboratory (NREL), 2008. Life Cycle Inventory of Biodiesel and Petroleum Diesel.
412. National Renewable Energy Laboratory (NREL), 4 October 2006. NREL, Chevron Establish Research Alliance to Advance Cellulosic Biofuels. [Online]. NREL Newsroom. Available at: http://www.nrel.gov/news/press/2006/445.html [Accessed on 10 November 2006].
413. NATTA, 1993. RENEW, 85, September-October.
414. NATTA, 1994. Windfarm Backlash, Compilation of Press Cuttings, vols I and II, NATTA, Milton Keynes.
415. Nature.com, 20 February 2008. Energy: Not Your Father's Biofuels. [Online]. Available at: http://www.nature.com/news/2008/080220/full/451880a.html [Accessed on 3 July 2008].
416. Nature.com, 2009. Company Information. [Online]. Available at: http://www.nature.com/npg_/company_info/index.html [Accessed on 9 July 2009].
417. Nature.com, 2009. Overview. [Online]. Nature Publishing Group. Available at: http://www.nature.com/npg_/company_info/index.html [Accessed on 23

December 2009].
418. Nature.com, 21 June 2007. Towards Better Biofuels. [Online]. Available at: http://www.nature.com/nature/journal/v447/n7147/edsumm/e070621-09.html [Accessed on 23 May 2009].
419. National Institute of Standards and Technology Special Publication, 2002. Information Security. Technology Administration U.S. Department of Commerce.
420. Nelson, T., 3 November 2006. Major Oil Companies Investments in Biofuels. [Online]. Yahoo Green. Available at: http://green.yahoo.com/blog/ecomii_healthy_living/62/major-oil-companies-investments-in-biofuels.html [Accessed on 10 November 2006].
421. Nestle Oil Corporation, 6 February 2007. Neste Oil's Biodiesel Project in France Discontinued. [Online]. Available at: http://www.nesteoil.com/default.asp?path=1;41;540;1259;1261;7440;7581 [Accessed on 27 April 2009].
422. North, D., 1990. Institutions, Institutional Change and Economic Performance, Cambridge University Press. pp.3.
423. NRC, 1983. Risk Assessment in the Federal Government: Managing the Process, Committee on the Institutional Means for Assessment of Risks to Public Health, National Research Council, National Academy of Sciences, National Academy Press, Washington, DC.
424. Nye, J. S. and Donahue, J. eds., 2000. Governance in a Globalising World, Brookings Institution, Washington, DC.
425. OECD-FAO, 2007. Agricultural Outlook 2007-2016. OECD Publications.
426. OECD, 2002. Guidance Document on Risk Communication for Chemical Risk Management. Series on Risk Management, no 16, Environment, Health and Safety Publications, OECD, Paris, France.
427. OECD, 2003. Emerging Risk in the 21st Century: An Agenda for Action. OECD Publication Service.
428. OECD, 2003. Emerging Systemic Risks in the 21st Century: An Agenda for Action, Final Report to the OECD Future Project, OECD, Paris, France.
429. OECD, 2008. Rising Food Prices: Causes and Consequences. OECD Agriculture Outlook.
430. Office of Government Commerce, 2007. Management of Risk: Guidance for Practitioners. Stationery Office.
431. Office of the Governor, 2 January 2007. Governor Schwarzenegger Announces $500 Million Grant to the University of California Berkeley to Establish Energy Biosciences Institute. [Online]. Available at: http://gov.ca.gov/index.php?/press-release/5307/ [Accessed on 12 March 2008].
432. Ogus, A., 1994. Regulation: Legal Form and Economic Theory. Oxford: Clarendon Press.
433. Oilgae, 2009a. Algae Harvesting: Flocculation. [Online]. Available at: http://www.oilgae.com/algae/har/flc/flc.html [Accessed on 24 August 2009].
434. Oilgae, 2009b. Algae Harvesting: Filtration. [Online]. Available at: http://www.oilgae.com/algae/har/fil/fil.html [Accessed on 24 August 2009].

435. Oilgae, 2009c. Algae Harvesting: Centrifugation. [Online]. Available at: http://www.oilgae.com/algae/har/cen/cen.html [Accessed on 24 August 2009].
436. Oilgae.com, 2009. Classification of Algae. [Online]. Available at: http://www.oilgae.com/algae/cla/cla.html [Accessed on 27 September 2009].
437. Omerod, R. 1996. Combining Management Consultancy and Research. In *Omega, International Journal Management Science,* 24(1), 1-12.
438. Organisation Internationale des Constructeurs d' Automobiles, 2008. World Ranking of Manufacturers Year 2008. World Motor Vehicle Production. OICA Correspondents Survey.
439. Pachauri, R. K., 2006. Introduction: Moving towards Biofuels fo a Secure and Clean Energy Future in Bhojvaid P.P., 2006. Biofuels: Towards a Greener and Secure Energy Future. The Energy and Resources Institute, India: pp. 6-10.
440. Paga, E. and Birol, F., 1994. Empirical Analysis of Oil Demand in Developing Countries, OPEC Review, 18(1).
441. Page, T., 1978. A Generic View of Toxic Chemicals and Similar Risks. Ecology Law Quarterly 7. pp. 207-244. In DeKay, M., Small, M.J., Fischbeck, P.S., Farrow, R.S., Cullen, A., Kadane, J.B., Lave, L.B., Morgan, M.G. and Takemura, K. 2009. *Risk-Based Decision Analysis in Support of Precautionary Policies.* In Loftstedt, R.E. and Boholm, A. eds., 2009. Risk. Earthscan.
442. Parker, R. H., 1991. Problems in the Development of Artificial Geothermal Energy Exploitation in Cornwall. In Proceedings of the Annual Conference of the Ussher Society. January 1991.
443. Parliamentary Office of Science and Technology, August 2007. Transport Biofuels. [Online]. Available at: http://www.parliament.uk/documents/post/postpn293.pdf [Accessed on 4 September 2008].
444. Patton, M. Q., 2002. Qualitative Research and Evaluation Methods (3rd ed). United Stated of America: Sage Publications, Inc.
445. Pearson, A. W., 1991. Managing Innovation: An Uncertainty Reduction Process. In Henry, J. and Walker, D. Managing Innovation. Sage/Open University.
446. Peltzman, S., 1976. Towards a More General Theory of Regulation. Journal of Law and Economics. Vol. 19, pp.211-240.
447. Philips, F. Y., 2001. Market-oriented Technology Management: Innovating for Profit in Entrepreneurial Times. Springer.
448. Philpott, T., 31 July 2008. World Bank Finally Releases “Secret” Report on Biofuels and the Food Crisis. [Online]. Grist. Available at: http://www.grist.org/article/biofuel-bombshell/ [Accessed on 1 October 2008].
449. Pitblado, R. and Turney, R., 1996. Risk Assessment in the Process Industries. The Institution of Chemical Engineers.
450. Prime Minister's Strategy Unit/ UK Cabinet Office, 2002. Risk: Improving Government's Capability to Handle Risk and Uncertainty, UK Cabinet Office, London, UK.
451. Pryor, F. L., 1974. Property and Industrial Organization in Communist and

Capitalist Nations, Indiana University Press. pp.338.
452. Putnam, H., 1975. The Meaning of “Meaning”. Minnesota Studies in the Philosophy of Science 7, pp.131–193.
453. Queen Margeret University, 2008. [Online]. Available at: http://www.qmu.ac.uk/the_university/key_features.htm [Accessed on 22 July 2008].
454. Raffensperger, C. and Tickner, J. eds., 1999. Protecting Public Health and the Environment: Implementing the Precautionary Principle. Washington, DC: Island Press.
455. Raiffa, H., 1968. Decision Analysis: Introductory Lectures on Choice Under Uncertainty. Reading. MA: Addison-Wesley. In DeKay, M., Small, M.J., Fischbeck, P.S., Farrow, R.S., Cullen, A., Kadane, J.B., Lave, L.B., Morgan, M.G. and Takemura, K. 2009. Risk-Based Decision Analysis in Support of Precautionary Policies. In Loftstedt, R.E. and Boholm, A. eds., 2009. Risk. Earthscan.
456. Rayner, S. and Cantor, R., 1987. How Fair is Safe Enough? The Cultural Approach to Societal Technology Choice. Risk Analysis. Vol. 7, pp.3-13.
457. RCEP (Royal Commission on Environmental Pollution), 1998. Twenty-first Report: Setting Environmental Standards, RCEP, London, UK.
458. Redding, C. W., 1970. Research Setting: Field Studies.
459. Reichardt, C. S. and Cook, T. D., 1979. Beyond Qualitative versus Quantitative Methods. In Coo, T. D. and Reichardt, C. S. eds., *Qualitative and Quantitative Methods in Evaluation Research*. pp. 7-32. Beverly Hills, CA: Sage.
460. Remenyi, D., Williams, B., Money, A. and Swarts, E., 1998. Doing Research in Business and Management: An Introduction to Process and Method. Sage Publication.
461. Renewable Fuel Agency, 7 October 2008. RFA First Interim Quarterly Report on Use of Biofuels in the UK.
462. Renewable Fuels Agency (RFA), 2008. About the RTFO. [Online]. Available at: http://www.renewablefuelsagency.gov.uk/aboutthertfo/rtfotargets [Accessed 12 January 2008].
463. Renewable Fuels Agency (RFA), 2010. RFA Quarterly Report 9: 15 April 2010=-14 July 2010. Provisional Data for the 2010/11 Obligation Year to date. [Online]. Available at: http://www.renewablefuelsagency.gov.uk/sites/rfa/files/27_RFA_quarterly_report_Apr_2010_July_2010%20R%20doc.pdf [Accessed on 31 August 2010].
464. Renewable Fuels Agency (RFA), 2010a. The UK Report to the European Commission under Article 4 of the Biofuels Directive. Promotion and Use of Biofuels in the UK during 2009.
465. Renewable Fuels Agency (RFA), 2010b. RFA Quarterly Report 9: 15 April 2010 to 14 July 2010. Provisional Data for the 2010/11 Obligation Year to Date.
466. Renewable Fuels Agency (RFA), 2010c. Certificates. [Online]. Available at: http://www.renewablefuelsagency.gov.uk/aboutthertfo/certificates [Accessed on 2 April 2010].

467. Renewable Fuels Agency, 2009. Frequent Ask Question. [Online]. Available at: http://www.renewablefuelsagency.org/faq.cfm [Accessed on 2 February 2009].
468. Renewable Fuels Association, 2005. Federal Regulations: Renewable Fuels Standard. [Online]. Available at: http://www.ethanolrfa.org/policy/regulations/federal/standard/ [Accessed on 1 February 2010].
469. Renewable Transport Fuel Obligations (RTFO) Order, 2007. Transport Energy: Sustainable and Renewable Fuels. [Online]. Available at: http://www.legislation.gov.uk/uksi/2007/3072/article/14/made [Accessed on 18 May 2008].
470. Renn, O., 2008a. What is Risk? In Renn, O. *Risk Governance: Coping with Uncertainty in a Complex World,* Earthscane**:** 1-12. Ch. 1.
471. Renn, O., 2008b. Pre-Assessment: Setting the Stage. In Renn, O. *Risk Governance: Coping with Uncertainty in a Complex World,* Earthscane**:** 47-52. Ch. 2.
472. Renn, O., 2008c. Appraisal. In Renn, O. *Risk Governance: Coping with Uncertainty in a Complex World,* Earthscane**:** 67-78. Ch. 3.
473. Renn, O., 2008d. Risk Evaluation. In Renn, O. Risk Governance: Coping with Uncertainty in a Complex World, Earthscane: 149-156. Ch. 5.
474. Renn, O., 2008e. Risk Management. In Renn, O. Risk Governance: Coping with Uncertainty in a Complex World, Earthscane: 173-184. Ch. 6.
475. Renn, O., 2008f. Risk Communication. In Renn, O. Risk Governance: Coping with Uncertainty in a Complex World, Earthscane: 201-204. Ch. 7.
476. Renn, O., 2008g. Conclusions. In Renn, O. Risk Governance: Coping with Uncertainty in a Complex World, Earthscane: 363-369. Ch. 10.
477. Righelato, R.,1 March 2007. Biofuels Report: Forest or Fuel. [Online]. The Ecologist. Available at: http://www.theecologist.org/investigations/energy/269092/biofuels_report_forests_or_fuel.html [Accessed on 1 March 2007].
478. Rip, A., 1995. Introduction of New Technology: Making Use of Recent Insights from Sociology and Economics of Technology. *Technology Analysis and Strategic Management,* Vol. 7., No.4.
479. Rip, A and Schot, J. W., 2002. Identifying Loci for Influencing the Dynamics of Technological Development. In Sorensen, K. H. and Williams, R. eds., 2002. Shaping Technology, Guiding Policy: Concept, Spaces and Tools. Edward Elgar. Chn. 5. pp. 145-162.
480. Rose, D. and Sullivan, O., 1996. Introducing Data Analysis for Social Scientists (2nd ed.) Buckingham, United Kingdom: Open University Press.
481. Rosenberg, N., 1976. Technological Change in the Machine Tool Industry. In Roserberg, N., 1976 Perspectives on Technology, New York: Cambridge University Press.
482. Rosenberg, N., 1994. Exploring the Black Box: Technology, Economics and History, Cambridge: Cambridge University Press.
483. Rosenberg, N., 1994. Uncertainty and Technological Change. In *Conference on Growth and Development: The Economics of 21st Century*, Standford

University. 3-4 June 1994. The United States of America.
484. Rosenbloom, R. S. and Kantrow, A. M., 1982. The Nurturing of Corporate Research. In Harvard Business Review. Harvard Business Publication. pp. 115-123.
485. Ross, D., 2002. Scuppering the Waves: How They Tried to Repel Clean Energy', Science and Public Policy, 29(1). pp. 25-35, February.
486. Roundtable on Responsible Soy Association (RTRS), 2008. About us. [Online] Available at: http://www.responsiblesoy.org/about_us.php [Accessed on 4 January 2008].
487. Roundtable on Responsible Soy Association (RTRS), 2010a. Implementation Manual P&C. [Online] Available at: http://www.responsiblesoy.org/index.php?option=com_content&view=article&id=57&Itemid=53&lang=en [Accessed on 1 June 2009].
488. Roundtable on Responsible Soy Association (RTRS), 2010b. About us. [Online] Available at: http://www.responsiblesoy.org/index.php?option=com_content&view=article&id=6&Itemid=9&lang=en [Accessed on 15 February 2010].
489. Roundtable on Sustainable Biofuels, 12 November 2009. Version One of the Principles and Criteria. [Online]. Ecole Polytechnique Federale De Lausanne. Available at: http://cgse.epfl.ch/page84341.html [Accessed on 1 December 2009].
490. Roundtable on Sustainable Biofuels, 13 August 2008. Global Principles and Criteria for Sustainable Biofuels Production. Version Zero. Ecole Polytechnique Federale De Lausanne.
491. Roundtable on Sustainable Biofuels, 2008. An Initiative of the EPFL Energy Centre. Ecole Polytechnique Federale De Lausanne.
492. Roundtable on Sustainable Palm Oil (RSPO), 2008a. What is RSPO? [Online] Available at: http://www.rspo.org/What_is_RSPO@.aspx [Accessed on 4 January 2008].
493. Roundtable on Sustainable Palm Oil (RSPO), October 2007. RSPO Principles and Criteria for Sustainable Palm Oil Production. Including Indicators and Guidance.
494. Rountable on Sustainable Palm Oil (RSPO), 2008b. Revised RSPO Principles and Criteria Document. [Online]. Available at: http://www.rspo.org/Revised_RSPO_Principles_-_Criteria_Document.aspx [Accessed on 5 January 2008].
495. Rountable on Sustainable Palm Oil (RSPO), 2010. Membership How to Apply. [Online]. Available at: http://www.rspo.org/?q=page/13 [Accessed on 17 February 2010].
496. Rowe, G. and Frewer, L. J., 2000. Public Participation Methods: A Framework for Evaluation, Science, Technology and Human Values, vol. 25, no. 1, pp. 3-29.
497. Rutherford, D., 2007. Economics: The Key Concepts. New York, Routledge. pp. 26.
498. Rutherford, D., 2009. Private Communication.
499. Sailer, S., 1981 quoted in the Financial Times, 18 May 1981.

500. Saita, F., 2007. Value at Risk and Bank Capital Management: Risk Adjusted Performances, Capital Management and Capital Allocation Decision Making. Academic Press.
501. Samociuk, M., Iyer, N. and Doody, H., 2010. A Short Guide to Fraud Risk. Gower.
502. San Francisco Business Times, 22 January 2008. Chevron Partners with Solazyme on Developing Biofuel from Algae. [Online]. Available at: http://www.bizjournals.com/eastbay/stories/2008/01/21/daily22.html [Accessed on 1 February 2008].
503. Sayer, A., 2000. Realism and Social Science. London: Sage.
504. Sayer, S., 2009. Private Communication.
505. Science Foundation Arizona, About SFAz. [Online]. Available at: http://www.sfaz.org/about-sfaz/about-sfaz.aspx [Accessed on 23 January 2008].
506. Scott, J. and Marshall, G., 2009. A Dictionary of Sociology. [Online]. Oxford University Press. Available at: http://www.oxfordreference.com/views/ENTRY.html?subview=Main&entry=t88.e1448 [Accessed on 5 July 2009].
507. Scottish Bioenergy, 2009. Welcome to Scottish Bioenergy. [Online]. Available at: http://www.scottishbioenergy.co.uk/ [Accessed on 12 July 2009].
508. Scottish Environmental Technology Network (SETN), 2007. Background Information. [Online]. Available at: http://setn.see.ed.ac.uk/index.php [Accessed on 3 August 2009].
509. Scottish Executive, 2006. Scotland's Climate Change Programme.
510. Scurlock, J., 2007. Biomass: Greening the Transport System. In Elliott, D. 2007. Sustainable Energy: Opportunities and Limitations. Palgrave Macmillan. pp. 49-67.
511. Searchinger, T., Heimlich, R., Houghton, R. A., Dong, F. Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., Yu, T., 2008. Use of US Croplands for Biofuels Increased Greenhouse Gases Through Land-Use Change. Science Express.
512. Segelken, R., 2009. Ethanol Fuel from Corn Faulted as “Unsustainable Subsidized Food Burning” [Online]. Available at: http://healthandenergy.com/ethanol.htm [Accessed on 1 June 2009].
513. Sekab Biofuels and Chemicals, 2009. Short Report from Emission TestUsin gLow Blend of Ethanol Derivative in Diesel Fuel.
514. Select Committee, 1984. House of Commons Select Committee on Energy, Session 1983-1984, Ninth Report, Energy, R&D in the UK. HMSO, London.
515. Select Committee, 2001. House of Commons Select Committee on Science and Technology, Session 2000-2001, In Seventh Report, Wave and Tidal Energy, HC 291, April, HMSO, London.
516. Self, P., 1985. Political Theories of Modern Government. London: Macmillan.
517. Shapira, Z., 1997. Risk Taking: A Managerial Perspective. Russell Sage Foundation.
518. Shell Springboard, 2009. Background. [Online]. http://www.shellspringboard.org/about/background [Accessed on 12 August 2009].

519. Shell Youtube Webchat, 2009b. Webchat Session with Graeme Sweeney. [Online]. Available at: http://www.youtube.com/watch?v=L29a1kb2QkA [Accessed on 9 April 2009]. drop chapter 7 date 8april2009
520. Shell YouTube, 2009a. [Online]. Available at: http://www.youtube.com/user/Shell [Accessed on 14 January 2009].
521. Shell, 1 February 2010. Shell and Cosan Sign MOU to Form Joint Venture in Brazil. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/press_releases/2010/shell_cosan_mou_brazil_01022010.html [Accessed on 16 February 2010].
522. Shell, 10 June 2009. Shell First to Sell Gasoline Blended with Advanced Biofuel. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/press_releases/2009/iogen_canada_10062009.html [Accessed on 12 June 2009].
523. Shell, 10 March 2009. Shell and Codexis Deepen Collaboration to Speed Arrival of Next Generation Biofuel. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/press_releases/2009/shell_codexis_collaboration_10032009.html [Accessed on 15 March 2009].
524. Shell, 11 December 2007. Shell and HR Biopetroleum Build Facility to Grow Algae for Biofuel. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/press_releases/2007/biofuels_cellana_11122007.html [Accessed on 13 January 2008].
525. Shell, 11 June 2009. Shell Blends Advanced Biofuel into Shell V-Power Gasoline Race Fuel at the 24 Hours of Le Mans Race. Available at: http://www.shell.com/home/content/media/news_and_library/press_releases/2009/biofuels_le_mans_11062009.html [Accessed on 1 July 2009].
526. Shell, 13 February 2009. Aberdeenshire Business Wins £40,000 Climate Change Innovation Prize. [Online]. Available at: http://www.shell.co.uk/home/content/gbr/aboutshell/media_centre/news_and_media_releases/2009/news/springboard_north.html [Accessed on 21 March 2009].
527. Shell, 13 July 2007. Q&A with Jan van der Eijk. [Online]. Available at: http://www.shell.com/home/content/innovation/news/shell_world_stories/2007/jan_vander_eijk_qa/ [Accessed on 28 October 2008].
528. Shell, 13 March 2010. Shell Blends Advanced Biofuels into Scuderia Ferrari Race Fuel for 2010 Formula One Season. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/press_releases/2010/advanced_biofuel_ferrari13032010.html [Accessed on 25 March 2010].
529. Shell, 13 October 2009. A Brief Look at the Future of Energy. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/speeches/2009/voser_energy_institute_13102009.html [Accessed on 26 October 2009].
530. Shell, 15 July 2008. Shell and Iogen Announce Extended Alliance to Accelerate a Next Generation Biofuel. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/press_releases/

2008/iogen_extended_alliance_15072008.html [Accessed on 22 July 2008].
531. Shell, 17 April 2008. German Chancellor Visits CHOREN to Mark Completion of Building Phase of World's First Commercial BTL Plant. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/press_releases/2008/visit_merkel_choren_17042008.html [Accessed on 19 April 2008].
532. Shell, 17 September 2008. Shell Announces Six New Biofuels Research Agreements.[Online]. Available at: http://www.shell.com/home/content/media/news_and_library/press_releases/2008/biofuels_research_agreements_17092008.html [Accessed on 28 September 2008].
533. Shell, 19 October 2010. Shell blends second advanced biofuel into Scuderia Ferrari race fuel at South Korea Grand Prix. [Online]. Available at: http://www.shell.com/home/content/media/news_and_media_releases/2010/biofuel_ferrari_south_korea_grand_prix_19102010.html [Accessed on 11 November 2010].
534. Shell, 2006. Shell Code of Conduct: How to Live by the Shell General Business Principles.
535. Shell, 2007a. Shell General Business Principles. 7th edition.
536. Shell, 2007b. Respecting Biodiversity. [Online]. Available at: http://www.shell.com/home/content/responsible_energy/environment/biodiversity/dir_biodiversity_000407.html [Accessed on 11 December 2008].
537. Shell, 2007c. Dealing with Specific Human Rights Issues. [Online]. Available at:http://www.shell.com/home/content/responsible_energy/society/using_influence_responsibly/human_rights/human_rights_issues/specific_human_rights_issues_16042007.html [Accessed on 14 December 2008].
538. Shell, 2007d. Answer Column. [Online]. Available at: http://www.shell.com/home/Framework?siteId=rotella-en&FC2=/rotella-en/html/iwgen/ask_our_expert/2008/zzz_lhn.html&FC3=/rotella-en/html/iwgen/ask_our_expert/2008/answercolumn_Q9_2008.html [Accessed on 2 July 2007].
539. Shell, 2008. Biofuels. [Online]. Available at: http://www.shell.com/home/content/aboutshell/our_business/fuels/biofuels/biofuels.html [Accessed on 21 December 2008].
540. Shell, 2009a. Shell and Biofuels: Finding a Sustainable Way Forward. 2009 Annual Report.
541. Shell, 2009b. Responsible Energy Sustainability Report 2008.
542. Shell, 2009c. I'm Not a Big Ego CEO Type. [Online]. Available at: http://www.shell.com/home/content/aboutshell/swol/2009/peter_voser_qa/ [Accessed on 18 August 2009]
543. Shell, 2009d. Inside Maranello-The Home of Ferrari. [Online]. Available at: http://www.shell.com/home/content/motorsport/ferrari/technical_partnership/inside_maranello/ [Accessed on 2 February 2009].
544. Shell, 2009e. The Partnership with Ducati. [Online]. Available at: http://www.shell.com/home/content/motorsport/ducati/shell_technical_partnership/partnership/ [Accessed on 2 March 2009].

545. Shell, 2009f. Alternative Energy. [Online]. Available at: http://www.shell.com/home/content/innovation/alternative_energy/ [Accessed on 22 April 2009].
546. Shell, 2009g. Hydrogen. [Online]. Available at: http://www.shell.com/home/content/innovation/alternative_energy/hydrogen/hydrogen.html [Accessed on 25 April 2009].
547. Shell, 2010a. Shell at a glance. [Online]. http://www.shell.com/home/content/aboutshell/at_a_glance/ [Accessed on 22 January 2010].
548. Shell, 2010b. Shell and Biofuels. Corporate Report.
549. Shell, 23 March 2010. Virent and Shell Start World's First Biogasoline Production Plant. [Online]. Available at: http://www.shell.com/home/content/media/news_and_media_releases/2010/biogasoline_production_plant_23032010.html [Accessed on 1 April 2010].
550. Shell, 23 November 2009. Shell and Waitrose Trial Waitrose Convenience Food at Shell Service Station. [Online]. Available at: http://www.shell.co.uk/home/content/gbr/aboutshell/media_centre/news_and_media_releases/archive/2009/news/shell_waitrose_trial.html [Accessed on 1 March 2010].
551. Shell, 23 October 2009. Future Trends in Raw Materials and Energy Sources in Europe. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/speeches/2009/ollila_koli_forum_23102009.html [Accessed on 12 November 2009].
552. Shell, 24 August 2007. A Nice Ride for Refineries-but will It Last? [Online]. Available at: http://www.shell.com/home/content/aboutshell/swol/july_sept_2007/rob_routs_24082007.html [Accessed on 26 January 2008].
553. Shell, 26 March 2008. Shell and Virent Announce Collaboration to Develop Biogasoline. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/press_releases/2008/biofuels_virent_26032008.html [Accessed on 3 April 2008].
554. Shell, 26 November 2009. Shaping the Future of Energy Togather. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/speeches/2009/voser_zurich_26112009.html [Accessed on 1 December 2009].
555. Shell, 28 May 2008. Shell Blends Next Generation Biofuel into Shell V-Power Diesel Race Fuel at the 24 Hours of Le Mans Race. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/press_releases/2008/biofuels_vpower_lemans_28052008.html [Accessed on 1 June 2008].
556. Shell, 29 October 2008. Q&A on Biofuels. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/speeches/2008/routs_biofuels_debate_29102008.html [Accessed on 1 December 2008].
557. Shell, 3 July 2008. Potentials of Conventional and Alternative Fuels. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/speeches/2008/r

outs_magdeburg_03072008.html [Accessed on 22 July 2008].
558. Shell, 6 November 2007. Shell and Codexis Expand Collaboration to Explore New Super Enzymes for Next-Generation Biofuels. [Online]. Available at: http://www.shell.com/home/content/media/news_and_library/press_releases/2007/biofuels_codexis_06112007.html [Accessed on 19 December 2007].
559. Shiels, M., 27 March 2003. Is Hydrogen the Fuel of the Future? [Online]. BBC. Available at: http://news.bbc.co.uk/1/hi/business/2880975.stm [Accessed on 21 January 2008].
560. Shotter, J., 1993. Conversational Realities: Constructing Life Through Language. London:Sage.
561. Shrader-Frechette, K. S., 1984. Risk-Cost Benefit Methodology and Equal Protection. In Covello, V.T. Menkes, J. and Mumpower, J. eds., Risk Evaluation and Management. Plenum, New York. pp. 275-296.
562. Shrader-Frechette, K. S., 1991. Risk and Rationality: Philosophical Foundations for Populist Reforms, University of California Press, Berkeley, CA.
563. Sijm, J.O.M., 2004. Induced Technological Change and Spillovers in Climate Change Policy Modelling. An Assessment. The Energy Research Centre of the Netherlands (ECN).
564. Simon, H. A., 1966. Administrative Behaviour. New York, Free Press. pp. xvi.
565. Sjoberg, L. and Drottz-Sjoberg, B.M., 2008. Risk Perceptions by Politicians and the Public. In *Energy and Environment*. Vol. 19. No.3+4, pp.455-483.
566. Slovic, P., Fischhoff, B. and Lichtenstein, S., 1982. Why Study Risk Perception? In Risk Analysis no 2, pp. 83-94.
567. Smith, C.G., 1996. Managing Technology in the Substitution Context. In Gaynor, G. H. ed., 1996. *Handbook of Technology Management*. McGraw-Hill. Ch. 22. pp. 22.3-22.23.
568. Smith, K. and Petley, D., 2009. Environmental Hazards: Assessing Risk and Reducing Disaster. Routledge.
569. Soetaert, W. and Vandamme, E., 2009. Biofuels. Wiley Blackwell.
570. Sorensen, B., 2004. Renewable Energy: Its Physics, Engineering, Use, Environmental Impacts, Economy and Planning Aspects. Academic Press.
571. SpecialChem, 2011. How to Reduce Risk and Incerase Speed of New Technology Introduction in Chemicals. SpecialChem.
572. SSP Shell, 2007. Policy Statement: Sustainable Sourcing of Biofuels Components. Sustainable Sourcing Policy.
573. Stern, P. C. and Fineberg, V., 1996. Understanding Risk: Informing Decisions in a Democratic Society, National Research Council, Committee on Risk Characterization. National Academy Press. Washington, DC.
574. Stevens, P., 2007. Oil Markets and the Future. In Helm, D. 2007. The New Energy Paradigm. Oxford University Press. pp. 123-157.
575. Stigler, G., 1971. The Theory of Economic Regulation. *Bell Journal of Economics and Management Science*. 2/1: pp.1-21.
576. Stiglitz, J. E., 2000. Economics of the Public Sector. Norton & Company Inc. pp.3-25.
577. Stirling, A., 2003. Risk, uncertainty and precaution: Some instrumental

implications from the social sciences, in Berkhout, F., Leach, M. and Scoones, I. eds., Negotiating Change. Elgar, London, UK, pp. 33-76.

578. Stoddard, W., 1986. The California Experience. Paper to the Danish Wind Energy Association Conference. In Karnoe, P., 1990. Technological Innovation and Industrial Organisation in the Danish Wind Industry. Entrepreneurship and Regional Development.

579. Strauss, A. and Corbin, J., 1990. Basic of Qualitative Research: Grounded Theory Procedures and Techniques. Newsbury Park, CA: Sage.

580. Stringer, G., 1971. The Theory of Economic Regulation. Bell Journal of Economics and Management Science. Vol. 2/1:pp.1-21.

581. Sunstein, C. R., 2004. Risk and Reason: Safety, Law and the Environment. Cambridge University Press.

582. Sustainable Bioenergy Centre (SBC), 2009. About Us. [Online]. Available at: http://www.bsbec.bbsrc.ac.uk/about/index.html [Accessed on 22 February 2009].

583. Sutherland, B., 2008. Climate Change Endangerd Habitats. [Online]. Available at: http://www.guardian.co.uk/environment/2008/mar/20/climatechange.endangeredhabitats [Accessed on 20 March 2008].

584. Synthetic Genomics, 14 July 2009. Synthetic Genomics Inc. and ExxonMobil Research and Engineering Company Sign Exclusive, Multi-Year Agreement to Develop Next Generation Biofuels Using Photosynthetic Algae. [Online]. Available at: http://www.syntheticgenomics.com/media/press/71409.html [Accessed on 15 July 2009].

585. Sztompka, P., 1991. Society in Action: The Theory of Social Becoming. Chicago: University of Chicago Press.

586. Taylor, S. J. and Bogdan, R., 1998. Introduction to Qualitative Research Methods: A Guidebook and Resource (3ed.). United Stated of America: John Wiley and Sons, Inc.

587. Teece, D. J., 1987. Profiting from Technological Innovation Implications for Integration, Collaboration, Licensing and Public Policy. In Teece, D. J. The Competitive Challenge: Strategies for Industrial Innovation and Research. Ballinger.

588. Texaco, 2010a. Chevron's History in the UK: [Online]. Available at: http://www.texaco.co.uk [Accessed on 1 March 2010].

589. Texaco, 2010b. Welcome to Chevron in the UK. [Online]. Available at: http://www.texaco.co.uk/ [Accessed on 1 March 2010].

590. The Energy and Resources Institute. 2008. About TERI. [Online]. Available at: http://www.teriin.org/index.php [Accessed on 23 May 2008].

591. The International Future Programme, 2009. Risk Management Policy. [Online]. Available at: http://www.oecd.org/department/0,3355,en_2649_35014780_1_1_1_1_1,00.html [Accessed on 12 May 2009].

592. The New York Times, 1 February 2006. Bush: America is Addicted to Oil. [Online]. Available at: http://www.nytimes.com/2006/02/01/world/americas/01iht-state.html

[Accessed on 18 November 2006].
593. The Royal Society, 2008a. Sustainable Biofuels: Prospects and Challenges. [Online]. Available at: http://royalsociety.org/Sustainable-biofuels-prospects-and-challenges/ [Accessed on 12 March 2008].
594. The Royal Society, 2008b. Biofuels: Prospects and Challenges. [Online]. Available at: http://royalsociety.org/news/metro/biofuels/ [Accessed on 27 June 2008].
595. The Royal Society, 2009. About Us. [Online]. Available at: http://royalsociety.org/about-us/ [Accessed on 22 December 2009].
596. The Royal Society, 2009. About Us. [Online]. Available at: http://royalsociety.org/about-us/?from=homemenu [Accessed on 25 May 2009].
597. The Scottish Entreprise, 17 August 2010. New Super Whisky Biofuels to Power Cars-I'll be Drammed! [Online]. Available at: http://www.scottish-enterprise.presscentre.com/Press-releases/New-super-whisky-biofuel-to-power-cars-I-ll-be-drammed-26b.aspx [Accessed on 1 September 2010].
598. The Scottish Executive, 2008. Scottish Business Grants. [Online]. Available at: http://www.scottishbusinessgrants.gov.uk/rsa/208.html [Accessed on 2 July 2008].
599. The Scottish Government, 17 October 2006. Funding for Green Fuel Production. [Online]. Available at: http://www.scotland.gov.uk/News/Releases/2006/10/17154211 [Accessed on 11 July 2008].
600. The Scottish Government, 2 November 2005. General Information: Scottish Executive Expertise, Knowledge and Innovation Transfer Programme (SEEKIT). [Online]. Available at: http://www.scotland.gov.uk/Publications/2005/11/02144913/49141 [3 August 2009].
601. The Scottish Government, 2007. Biomass Action Plan for Scotland. [Online]. Available at: http://www.scotland.gov.uk/Publications/2007/03/12095912/8 [Accessed on 8 June 2007].
602. The Scottish Government, 2008a. Scotland in the EU. [Online]. Available at: http://www.scotland.gov.uk/Topics/Government/International-Relations/Europe/European-Union/Scotland-in-EU [Accessed 6 April 2008].
603. The Scottish Government, 2008b. Bioenergy. [Online]. Available at:http://www.scotland.gov.uk/Publications/2008/11/05115324/9 [Accessed on 17 May 2008].
604. The Scottish Government, 2008c. Cleaner Vehicles and Alternative Fuels. [Online]. Available at: http://www.scotland.gov.uk/Topics/Transport/sustainable-transport/sus-trans-team [Accessed on 18 December 2008].
605. The Scottish Government, 2008d. Draft Framework for the Development and Deployment of Renewables in Scotland. [Online]. Available at:http://www.scotland.gov.uk/Topics/Business-Industry/Energy/Energy-sources/19185/Resources/20801/Renewables-framework/REFSummary [Accessed on 18 December 2008].

606. The Scottish Government, 2009. Consultation on Low Carbon Vehicles (CLCV). Sustainable Transport Team. Transport Directorate.
607. The Scottish Government, 2009. Renewables Action Plan (RAP). Renewable Energy Division.
608. The Scottish Parliament, 2008. How the Scottish Parliament Works. Office of Public Sector Information. Scotland Act 1998 C. 46, Schedule 5.
609. The UK Agriculture, 2009. UK Crops Sitemap. [Online]. Available at: http://www.ukagriculture.com/sitemap_uk_crops.cfm [Accessed on 12
610. The UK Legislation, 2008. Climate Change Act 2008. Chapter 27.
611. The UK Petroleum Industry Association, April 2009. Biofuels in the UK. [Online]. Available at: http://www.ukpia.com/industry_issues/fuels/biofuels-and-alternative-fuels.aspx [Accessed on 7 July 2009].
612. Thomas, P., March 2007. The Ecologist's Special Report on Biofuels. [Online]. Available at: http://www.theecologist.org/archive_detail.asp?content_id=838 [Accessed on 12 April 2007].
613. Thomson, M., Ellis, W. and Wildavsky, A., 1990. Cultural Theory. Westview Press, Boulder, Co.
614. Thorpe, T., 1992. A Review of Wave Energy. ETSU Report R-72. Energy Technology Support Unit. Harwell.
615. Thurmond, W., 2008. Biofuels' Bright Future. [Online]. Available at: http://www.forbescustom.com/EnvironmentPgs/BiofuelsP1.html. [Accessed on 22 April 2008].
616. Titterton, M., 2005. Risk and Risk Taking in Health and Social Welfare. Jessica Kingsley Publishers.
617. Total, 2009. Seeking the Most Sustainable Conversion Methods. [Online]. Available at: http://www.total.com/en/our-energies/alternative-energy/biomass-940930.html [Accessed on 1 May 2009].
618. Transcript the Webchat Session with Graeme Sweeney, Executive Vice President of Future Fuels and CO2 at Shell. 7 April 2009. [Online]. Available at: http://www.shelldialogues.com/biofuels [Accessed on 7 April 2009].
619. Trist, E. L., 1981. The Evolution of Socio-Technical Systems: A Conceptual Framework and An Action Research Program. Ontario Quality of Working Life Centre, Occasional Paper no. 2.
620. Trott, P., 2005. Managing Innovation within Firms. In Innovation Management and New Product Development. pp. 79-82.
621. Tulloch, J. and Lupton, D., 2003. Risk and Everyday Life. Sage Publications Ltd.
622. Twidell, J and Weir, T., 2006. Renewable Energy Resources. Taylor & Francis.
623. United Nations Brundtland Commission, 1987. Our Common Future. Report of the World Commission on Environment and Development.
624. United Nations Environment Programme, March 2009. Global Green New Deal Policy Brief, UNEP.
625. United Nations Framework Convention on Climate Change (UNFCCC), 2008. Kyoto Protocol. Available at: http://unfccc.int/kyoto_protocol/items/2830.php [Accessed on 1 February

2008].
626. United States Department of Agriculture (USDA), 18 February 2009. Corn Trade. [Online]. Available at: http://www.ers.usda.gov/Briefing/corn/trade.htm [Accessed on 1 March 2009].
627. United States Department of Agriculture (USDA), 8 December 2008. Soybean and Oil Crops. [Online]. Available at: http://www.ers.usda.gov/Briefing/SoybeanOilCrops/ [Accessed on 1 January 2009].
628. United States Environmental Protection Agency, 2009. EPA Proposes New Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond. [Online]. Available at: http://www.epa.gov/OMS/renewablefuels/420f09023.htm [Accessed on 1 February 2010].
629. United States Environmental Protection Agency, 3 February 2010. Regulations. Renewable Fuel Standard Program (RFS2) Final Rule. [Online]. Available at: http://www.epa.gov/otaq/renewablefuels/ [Accessed on 11 February 2010].
630. University of California Davis, 19 September 2006. Chevron to Fund Major Biofuels Research Projects at UC Davis. [Online]. Available at: http://www.news.ucdavis.edu/search/news_detail.lasso?id=7873 [Accessed on 2 October 2006].
631. University of Dundee, 27 January 2009. Biggest Ever Public Investment in Bioenergy to Help Provide Clean, Green and Sustainable Fuels. [Online]. Available at: http://www.dundee.ac.uk/pressreleases/2009/prjan09/bioenergy.htm [Accessed on 22 February 2009].
632. Van de Poel, I., 1998. Changing Technologies: A Comparative Study of Eight Processes of Transformation of Technological Regimes. Enschede: Twente University Press.
633. Van der Sluijs, J. P., Risbey, J. S., Kloprogge, P., Ravetz, J. R., Funtowicz, S. O., Corral Quintana, S., Guimaraes Pereira, A., De Marchi, B., Petersen, A. C., Janssen, P. H. M., Hoppe, R. and Huijs, S. W. F. 2003. RIVM/ MNP Guidance for Uncertainty Assessment and Communication, Report no NWS-E-2003-163, Copernicus Institute for Sustainable Development and Innovation and Netherlands Environmental Assessment Agency, Utrecht and Bilthoven, The Netherlands. In Renn, O. Risk Governance: Coping with Uncertainty in a Complex World, Earthscane: 173-184. Ch. 6.
634. van Maanen, J., 1983. Qualitative Methodology. Sage.
635. Verenium Corporation, 2009. About Verenium Corporation. [Online]. Available at: http://www.diversa.com/about.asp [Accessed on 4 January 2009].
636. Vidal, J., 15 February 2010. EU Biofuels Significantly Harming Food Production in Developing Countries. [Online]. The Guardian. Available at: http://www.guardian.co.uk/environment/2010/feb/15/biofuels-food-production-developing-countries [Accessed on 15 February 2010].

637. Vidal, J., 22 January 2010. One Quarter of US Grain Crops Fed to Cars, Not People. New Figures Show. [Online]. The Guardian. Available at: http://www.guardian.co.uk/environment/2010/jan/22/quarter-us-grain-biofuels-food [Accessed on 22 January 2010].
638. Virent Energy System Inc, 2008. Our Story. [Online]. Available at: http://www.virent.com/MeetVirent/our_story.html [Accessed on 12 June 2008].
639. Viscusi, W. K., 1994. Risk-Risk Analysis. Journal of Risk and Uncertainty, Vol 8, pp. 5-18.
640. Voigt, S. and Engerer, H., 2002. Institutions and Transformation: Possible Policy Implications of the New Institutional Economics. In Zimmerman, K. Frontiers in Economics. Berlin. Springer-Verlag. pp.132.
641. von Wedel, R., 1999. Technical Handbook for Marine Biodiesel. US Department of Energy.
642. von Winterfeldt, D. and Edwards, W., 1984. Patterns of Conflict about Risk Debates. Risk Analysis, vol. 4, pp. 55-68.
643. Vose, D., 2008. Risk Analysis: A Quantitative Guide. John Wiley & Sons. 3rd ed.
644. Walker, S., 1993. Down on the Windfarm, NATTA Report, Milton Keynes.
645. Warwick, D. P. and Lininger, C. A., 1975. The Sample Survey: Theory and Practice. McGraw-Hill. pp.127.
646. Watzlawick, P. ed., 1984. The Invented Reality. London: Norton.
647. Weber, K. M., 2002. The Political Control of Large Socio-technical Systems: New Concepts and Empirical Applications from a Multi disciplinary Perspective. In Sorensen, K. H. and Williams, R. Shaping Technology, Guiding Policy: Concepts, Spaces and Tools. Edward Elgar Publishing Limited. pp. 325-358.
648. Weinberg, A. M., 1972. Science and Trans-science, Minerva, vol. 10, pp. 209-222.
649. Wengenmayr, R. and Buhrke, T., 2008. Renewable Energy: Sustainable Energy Concepts for the Future. Wiley.
650. Westermann, P., Haberbauer, P. and Lens, M., 2006. Biofuels for Fuel Cells: Biomass Fermentation Towards Usgae in Fuel. IWA Publishing.
651. Weyerhaeuser Company, 12 April 2007. Chevron and Weyerhaeuser Create Biofuels Alliance. [Online]. Available at: http://www.weyerhaeuser.com/Company/Media/NewsReleases/NewsRelease?dcrId=07-04-12_ChevronWeyerhaeuserCreateBiofuelsAlliance [Accessed on 10 June 2007].
652. Whatagreencar.com, 2008. Bioethanol and Biodiesel. [Online]. Available at: http://www.whatgreencar.com/biofuels.php [Accessed on 3 March 2008].
653. White, C. and Fan, M., 2006. Risk and Foreign Direct Investment.
654. Wiener, J. B., 1998. Managing the Iatrogenic Risks of Risk Management, Risk: Health Safety and Environment, vol 9, pp. 39-83.
655. Wilkinson, D. and Birmingham, P., 2003. Using Research Instruments A Guide for Researchers. London, United Kingdom: Routledge Falmer.
656. Williams, R and Edge, D., 1996. The Social Shaping of Technology. In

Research Policy. Vol. 25, pp.856-899.
657. Wilson, G., 1990. Interest Group. Oxford. Oxford University Press.
658. Wilson, G., 1990. The Politics of Regulation. New York: Basic Books.
659. Woodman, G. and Klippel, D., 2009. Risk and the Law. Routledge-Cavendish.
660. Workman, D., 22 June 2007. Top Ten Sugar Exporters.
661. World Biofuels Markets, 17 March 2009. Sustainable Biofuels Awards: 2009 Winners Announced at Brussels Conference. [Online]. Available at: http://www.greenpowerconferences.com/wbm_2009/awards/index.html [Accessed on 20 April 2009].
662. World Business Council for Sustainable Development, 2004. Energy and Climate Change Facts and Trends to 2050.
663. World Encyclopedia, 2008. Oxford University Press.
664. Worldwatch Institute, 18 February 2009. Time to Get Smart on Biofuels. [Online]. Available at: http://www.worldwatch.org/smartchoicesforbiofuels [Accessed at 2 April 2009].
665. Worldwatch Institute, 2007. Biofuels for Transport: Global Potential and Implications for Sustainable Energy and Agriculture. Worldwatch Institute.
666. Worldwatch Institute, 2008. Biofuels for Transport. Global Potential and Implications for Sustainable Energy and Agriculture. Earthscan. Ch. 3. pp. 24.
667. Worldwatch Institute, 2009. About WorldWatch. [Online]. Available at: http://www.worldwatch.org/About [Accessed at 19 January 2009].
668. Worldwatch Institute, 8 October 2007. Better than Corn? Algae Set to Beat Out Other Biofuel Feedstock. [Online]. Available at: http://www.worldwatch.org/node/5391 [Accessed on 19 October 2007].
669. Worldwide Fuel Charter Committee, March 2009. Ethanol Guideline. [Online]. Available at: http://oica.net/wp-content/uploads/ethanol-guideline-final-26mar09.pdf [Accessed on 18 July 2009].
670. WRA, 2009. About Us. [Online]. Available at: http://www.wraconferences.com/2/5/index.php [Accessed on 1 November 2009].
671. Yin, R. K., 1994. Case Study Research: Design and Methods. Sage Publications.
672. Yin, R. K., 2003. Applications of Case Study Research. Thousand Oaks: Sage Publications
673. Yuksek, L., Kaleli, H., Ozener, O. and Ozoguz, B., 2009. The Effect and Comparition of Biodiesel-Diesel Fuel on Crankcase Oil, Diesel Engine Performance and Emissions. FME Transactions. Vol. 37, No. 2.
674. Zalan, T. and Lewis, G., 2004. Writing About Methods in Qualitative Research: Towards a Transparent Approach. In Marschan-Piekkari, R and Welch, C. eds., *Handbook of Qualitative Research Methods for International Business*. Cheltenham, United Kingdom: Edward Elgar Publishing Ltd.
675. Ziegler, J., 2007. Right to Food. [Online].Available at: http://www.righttofood.org/new/html/JeanZiegler.html [Accessed on 1 August 2007].
676. Zikmund, W. G., 2003. Business Research Methods (7th ed.) Ohio, United Stated of America: Thomson South-Western.

677. Zinn, J. O. and Taylor-Gooby, P., 2006. The Challenge of (Managing) New Risks, In Taylor-Gooby, P. and Zinn, J. eds., Risk in Social Science, Oxford University Press, Oxford, UK, pp. 54-75.

678. Zoellick, R., 2008. Food Price Surge Could Mean 7 Lost Years in Poverty Fight. [Online]. Available at: http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:21726628~pagePK:64257043~piPK:437376~theSitePK:4607,00.html [Accessed on 6 June 2008].

Table of Contents for Appendix

Appendix 1.1 Technological Change

The notion of induced technological change (TC) was firstly introduced by Hicks (1932). He noted that, changes in relative prices of production factors such as labour/capital, would spur the development and diffusion of new technology in order to economise on the usage of more expensive production factor. Starting from 1960s, this notion of induced TC has been used by the "endogenous" or "new" growth theory to account for economic growth and TC endogenously within a macro economic model. Subsequently, the idea of induced TC has been applied to a variety of other disciplines. More recently (since the mid-1990s), it has also been used in the field of energy, environmental economics and climate policy modelling (Sijm, 2004).

According to Sijm (2004), the process of TC covers the widely used Schumpeterian trilogy of invention[303], innovation[304] and diffusion[305]. In his paper, the induced TC is defined as the component of TC that is brought about in response to government climate policy. Climate policy is primarily aimed at reducing the GHG/CO_2 emissions, and includes both market-based instruments (taxes, subsidies and tradable permits) and command-and-control regulations (setting performance, targets or technological-based standards for firms).

Appendix 2.1.1 The Value Chains of Oil and Biofuels

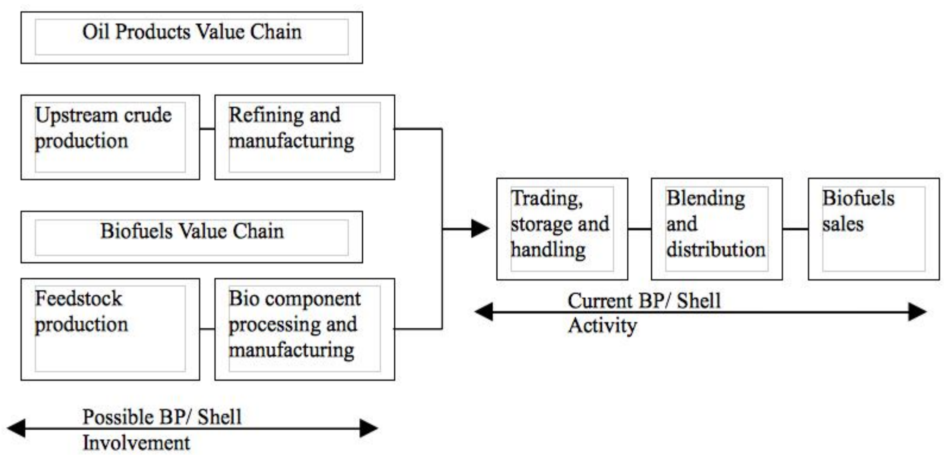

Figure 2.1.1 The Value Chains of Oil and Biofuels (Shell, 2010b).

There is a rudimentary strong correlation between biofuels and hydrocarbon. During the introduction of the UK Renewable Transport Fuels Obligation (RTFO[306]) in 2008-2010, BP and Shell started buying biofuels on the international market, blending biofuels with petrol/diesel and then supplying to the UK market. Therefore, the downstream activities of biofuels blending with hydrocarbon have been in place since the execution of hydrocarbon supply.

303 the first development and demonstration of a scientifically/technically new product or process.
304 the first regular commercial production of a new technology.
305 the spread of a new technology across its potential market.
306 The RTFO requires the UK's transport fuel suppliers to ensure 5% of all road vehicle fuels supplied are from biofuels by 2013/2014.

Appendix 2.1.2 Types of Rules and the Means of Enforcement for the Government and the Oil Companies under the UK Biofuels Regulated Market

Supported by Voigt and Engerer (2002), five types of rules and enforcement are given in Table 2.1.1.

By operating within the UK BRM, rules are steering a complex series of profit maximising aims for the oil companies; while also guiding the government's responsibilities to achieve public socioeconomic welfare (conventional). Both the government agencies and the oil corporations have established sets of internal rules (private) which lead towards better performances[307], and which can then be evaluated by the public (customs). The oil companies are adopting state laws into their operations, while contributing in some socioenvironmental instances under their corporate social responsibility (ethical).

In addition, the regional laws from the EU are influencing the UK Government (as a member state of the EU) in some of the UK policy formulations, as well as

Table 2.1.1: Rules as Guidelines for the Government and the Oil Companies under the UK Biofuels Regulated Market (BRM)

Rules	Enforcement	Relevance to biofuels development and deployment
Convention	Self-enforcing	The government (the ruling party) tries to sustain its ultimate political authority (to be reelected) for sustainable governance, while the oil companies strive for profit maximisation. However, apart from fulfilling their respective goals, both institutions are obliged to achieve socioeconomic development and environmental protection. Therefore, they have to collaborate with each other in order to execute biofuels supply and biofuels development in the UK, for the sake of social, economic and environmental benefits.
Ethical	Self-commitment	Gradually being practised by the oil companies as a corporate social responsibility. By showing a more humanistic business attitude[308] which differss from their previous motive-which was solely profit maximisation. Inevitably, practising ethical rules will build a more positive image for the oil companies, whom are morally and ethically responsible to the social, economic and environmental implications. This will raise the oil companies' social stature, and gain higher reputation and recognition.
Customs	Informal social control	The British public empowers the government (through ballot box) to run the country, while at the same time buying the oil companies' biofuels and therefore materialising the companies' profit making aim. Hence, a society has a forceful influence if it acts collectively as one entity. In addition, some social representations (environmentalists/social movements and media) are scrutinising the government policies (formulation and implementation) and the private companies' business executions. These social groups are acting as the third force, by lobbying their diversified interests, and justifying their roles in protecting the public's welfares on social, economic and environmental issues.

307 Financial performance for the oil companies, which is to generate wealth for the shareholders and to secure employment for its members who are working in the company. The government is responsible to safeguard social harmonisation, environmental protection, national/local economic development, returns on public investments, higher employment opportunities and others.

308 In biofuels plantation, the oil companies are showing concerns to the local environment (by not polluting the biodiversity) and assuming responsibility for their employees (health and safety, no forced/child labours). For the NGB development, the oil companies funding R&D projects generate knowledge transfer (from academic/commercial biotechnology institutions to the public), employment opportunity (research jobs) and safeguarding the social and environmental concerns (by seeking non-food biofuels feedstocks) after the emergence of systemic risks.

Private	Organised private enforcement	Public agencies and the oil companies have a number of sets of private rules to ensure their efficient execution and their operations can be measured such as: Quality and Standard, ISOs, Codes of Conduct, Business Principles, management, corporate rules and others. Some of them will publish their performances using corporate annual reports, civil service and efforts accomplishment reports. The recently established biofuels roundtables have pulled in both public agencies and the oil companies, in order to working on issues about green and sustainable (G&S) biofuels production.
State Law	Organised state enforcement	The contributions of biofuels had some positive effects on national economic growth. Thus, sets of regulations have been enforced through policies, directives[309], mandatory targets and regulations, all of which are in place to control the oil companies' biofuels supply. After the emergence of the systemic risk, the G&S requirements have been prioritised by the UK Renewable Fuel Agency (RFA), whilst the oil companies are obligated to comply with these two requirements in their monthly reporting system to the RFA.

Source: The researcher utilised Voigt and Engerer (2002) framework. pp. 132. Ch. 2 and adopted it for the UK BRM

governance and administration (state). Therefore, rules provide clear roles and responsibilities, and fundamentally assign the government and the oil companies into their respective responsibilities of operations and commitments. This will not only ensure effective executions, but will also handle any problems/R&U encountered during routine operations as well as the processes of decision-making.

Appendix 2.1.3 Five General Types of Institution for the UK Biofuels Regulated Market

The UK BRM has two main actors: the UK Government (linking with the EU and the devolved government like the Scottish Government, SG) and the oil companies. The political character of the regulatory actions and the socioeconomic motivations are mediated through the domestic market.

The BRM is a market, where there is a degree of supervision/intervention by the governments concerning permissible price movements and market behaviour for biofuels adoption. The oil companies are responsible for the consistent biofuels supply[310] according to the obligated annual targets of the RTFO. Therefore, the operations of the BRM are guided by rules (as discussed at appendix 2.1.2), and motivated by the respective interests of the actors and secured by commitments.

By using five general types of institution (FGTI) advocated by Gregory and Stuart (2004): the structure of BRM, mechanisms in place, institutional arrangements, and the interactions between the governments and the oil companies could be explained further (summarised in Table 2.1.2).

(a) Principal versus Agent

The UK BRM at the policy-making level, most decisions are made at the highest

309 Directive is a European statute adopted by the Council of Ministers, and must be enacted by member states through a national Act of Parliament or an equivalent measure. Directives typically set out a framework of principles and legislative objectives, which is given in greater detail as it is transposed into national law, regulations or collective agreements (Edmund and Noon, 2008).

310 Biofuels have to be distributed which are convenient for accessibility, constant for availability and quantity, and consistent in quality. Under the RTFO, all oil companies are obligated to comply with the annually increasing targets of biofuels blend in petrol/diesel.

level of a regional political authority-the EU. These decisions are then passed down to the respective member states of the espective national level like the UK Government to enact. In reality, the EU is formed by the representatives from each of the member states. Therefore, most of the decisions made are near unanimous. Biofuels activation was due to the EU/UK Governments' mandate. Through regional and national policies formulation to have biofuels implemented. This top-down approach to political power reflects the institution, and is influenced by the market structure of the EU under the Single Market principle.

At a national level, the UK Government acts as the national principal, with the executive legislative power and links with the devolved governments like the SG, and passes regulatory decisions made[311] to the oil companies (agents) as the biofuels suppliers. The principal-the UK Government is responsible for the national policy executions, and for monitoring the oil companies' performances, in order to ensure the SG is adopting regional biofuels policies and the oil companies are supplying biofuels, which specifically comply with the state law.

An agency created by the Department for Transport (DfT)-the Renewable Fuel Agency (RFA), is an agent of the DfT. Therefore the RFA is empowered by the DfT, to monitor biofuels deployment in the UK, through the monthly biofuels carbon and sustainability[312] reporting systems feedback by the oil companies. What is signified from these principal-agent relationships is that, there are many overlapping roles taking place. A principal could be also acting as an agent for another principal. For example, the UK Government acts as an agent for the EU Government, yet it is also the principal in the UK. The RFA acts as an agent for the DfT, simultaneously also playing a role as the principal for the oil companies. Thus, these identifications are merely to present the relationships, interactions and the responsibilities which separate the decision makers and the decision executors.

(b) Market and Plan

Gregory and Stuart (2004) advocate, market and plan are two mechanisms for providing information and to coordinate decisions within biofuels deployment and development. Plan is a tool to control biofuels execution; while market is to manage a supply-and-demand function. Utilities like biofuels involve very high transaction costs which need the participation of both regulators and the oil companies, in order to ensure the effective implementation within a nation. Therefore, the UK BRM has the combination of both plan and market mechanisms. This could be justified as follow:

Biofuels are an important commodity. Without them, the initial UK target for quicker road transport CO_2/GHG reduction would not materialise. The production of biofuels affects other sectors of the economy, by generating wealth in agriculture, biofuels manufacturers and biofuels research institutions. The benefit of a regulated market versus a free market is that, many times a free market works less than perfectly, and fails in some cases when dealing with such a large social technology like biofuels.

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311 Information is appeares in the form of policies, directives, acts, regulations, standards and mandatory targets of biofuels.

312 the quantity sold on particular month, the source of the biofuels and the CO_2 savings achieved.

Firstly, the security of biofuels supply is important to the domestic consumer. This requires that biofuels capacity must be consistently available, at all time for road transport use. To solve the security problem, some regulations have been implemented; which require the oil companies to provide appropriate levels of investment and commitment of supply. Secondly, externalities arise when the private costs of production and consumption are not equal to those of society. The solution is the incentive provision, which partially absorbs and lowers the production cost, while maintaining an affordable retail prices so that domestic consumers will be able to afford their products.

Thirdly, the time scale associated with the decision and execution on biofuels is for long-term. It also follows from the sheer size and the scope of projects: R&D, infrastructure development and production plants construction are among the largest investments in biofuels economies. Therefore, market forces alone might not be capable of dealing with the long-term planning that these decisions require.

The current decisions on biofuels deployment are mainly made by the policy makers and reflect the interests of future consumption, price and the concerns over safeguarding the socioenvironmental in a sustainable manner. Many corporate biofuels R&D projects run over an extended period of time, and the longer the investment time period, the greater the degree of R&U over future returns. This is where the role of the government is required. The government intervention could ameliorate the R&U situation by supporting the future of biofuels through positive political messages (biofuels would sustain to 2020 and beyond under the RTFO) in order to convince the oil companies of promising biofuels business prospects after their huge investments have been incurred.

Fourthly, even if a competitive market in biofuels were desirable, it is still not yet feasible. Many areas of biofuels and hydrocarbon are supplied through the oil companies seem to be naturally oligopolistic. Therefore, biofuels have been concentrated in the hands of a few major firms, which have sought to influence the markets they operate. The existence of an oligopoly structure with the absence of competitive pressure has proved a motive for a government intervention.

Furthermore, under the free market principles, the costs of investment by the oil companies could be recouped, by imposing extremely high future prices when the company's investments have been brought into operations. The oil companies might be induced to provide a margin by the prospect of the revenues they could gain, once the results of their R&D projects have been attained. Since biofuels comprises a substantial proportion of the household budgets of the poor, the pricing policy of biofuels is likely to have a considerable impact on poverty, and the poor should be protected directly through lower fixed prices for affordability (Helm, et al., 2000). In order to do so, the government is required to play its role in safeguarding those who might find it unaffordable.

Because the free market setting has its limitations, it could be challenged for security of supply, externalities, long-term commitment and the degree of competitiveness which might lead to social exploitation and inequality. The government is required in order to manage, control and monitor, ensuring that the utility could reach everyone while protecting the social interests. This is supported by Stiglitz's (2000), the government must take an active role in balancing the economic system and alleviating the worst aspects of energy poverty, while private enterprises should be allowed to play the central role in the economy.

(c) Control and Income

Under the UK BRM, the economic system is mixed which consisting of both private and public decisions. Biofuels supply is carried out by a few oil companies operating in the UK market, while the government grants the licences to the oil companies to run their businesses on oil extraction, refinery and supply. In return, the oil companies are paying excise duties and sales taxes to the government. This is where the oil companies make a major financial contribution to the government treasury. These royalties are often the main source of the government revenue, and the taxes collected are used to achieve the desired socioeconomic distribution. Besides, the government will support the product (biofuels blend with hydrocarbon) through taxes, incentive system and the retail prices are set through subsidies[313]. Under this framework, consumers with a high preference for price stability can purchase biofuels blend with hydrocarbon with ease of mind.

There are three control components under the UK BRM: Firstly, some international structures which follow the natural characteristics of oil industry and its cross border market setting, such as the biofuels quality control[314]. Secondly, a respective national regulatory system (like the RFA) to manage, control and monitor the market with biofuels blends supply, but which would not interfere the oil companies' businesses operations, unless the objections raised were from the social control. Thirdly, an information system which allows for the inter-monitoring between the government and the oil companies, as well as both parties generating information to the society for the public concerns.

The oil companies' lucrative financial contributions have enriched the government's treasury for so many decades. Hence, the leeway of the oil companies’ business operations is fitted into capitalist principles. This freedom would ensure the oil companies could run their businesses with the highest efficiency and generate more revenues for the companies/shareholders, as well as for the government. This explains that, even though under the regulated market, it is the market context of supply-and-demand that being controlled, and not the oil companies’ business functions.

(d) Incentives

Ideally, if the government (principal) had perfect information, incentives would not be necessary. However under the BRM, the complexity of biofuels production sources and supplies, the principal typically lacks such perfect information. The oil companies (agents) know much more about local circumstances, and have higher

313 Biofuels subsidies cost approximately £550m annually (BBC News, 26 August 2008).

314 The biofuels standards have to be complied with the European Standards: on the biodiesel EN 14214 (2003) and the bioethanol EN15376, to foster regional trades and products' standard unifications.

control on the biofuels value chain than the principal. Therefore, the agents gain local decision-making authority in a number of realms. The government, thus, needs to devise an incentive system that will induce the oil companies to act in the interests of the government (mandate of biofuels). This is because, if the principal's incentive system is flawed, then the agent will not act in the interest of the principal.

Under the UK BRM, the UK Government utilises financial incentives to motivate the oil companies. According to the Department for Transport (2008), the UK Government's support is through fuel duty incentives. Biodiesel and bioethanol are taxed at 20p/litre less than fossil petrol and diesel. This support is guaranteed until March 2010. The biodiesel incentive has been in place since July 2002, while bioethanol's was introduced in January 2005. The aim for this is to keep the biofuels production cost low, in order to pass on to the market, ensuring affordable prices to the consumers.

(e) The Role of the Government
Several EU/UK broad biofuels policy areas are prioritising some regional/national political, social and economic agendas. The collective aims are to reduce imported oil demand, develop the next generation biofuels (NGB) technologies, cutting GHG emissions and increase domestic supplies of biofuels from home agriculture power. However it is more complex than it might first seem. There are some other options that have been suggested such as reducing the use in the transportation sector, to keep further improvements in automotive fuel efficiency and to encourage alternative technologies for automobile.

Since biofuels execution is under the EU/UK Governments' mandate, effectuating the biofuels programme regionally and the RTFO nationally would challenge the institutional knowledge and experiences of the EU/UK Government for such a new and large scale of technological application. The good news is that, there is consistent collaboration and support from the oil companies, which allow both to work together to ensure the effective execution of biofuels. The government is playing its role as the principal. Through policies formulation, biofuels standards are set up and incentives provided to ease biofuels execution, while passing the baton of the execution roles to the oil companies for biofuels supply.

Summary
The analysis of using FGTI (summarised in table 2.1.2), even though simple, it could describe some of the basic mechanisms, interactions, structures and operations taking place within the UK BRM (shown in figure 2.1.2). The BRM allows private businesses to pursue their own private economic objectives; simultaneously accepting the influence/interventions of the governments to achieve the public's socioeconomic and environmental objectives.

Table 2.1.2: Adoption of the FGTI in the UK BRM

FGTI	Energy Economics	Explanation on the UK BRM
(a) Decision-making structure -Rules as guidelines (refer appendix 2.1.2) -Principal versus agent	Primarily Decentralised	The oil companies formed an oligopolistic market structure, operating under regulated mechanism intervenes by the political authorities. The UK Government and the SG act as the principals, while the oil companies are the agents-the suppliers for biofuels execution. Generally they are tied by the rules-as guidelines of their respective roles and responsibilities (refer appendix 2.1.2).
(b) Mechanisms for Information provision and Coordination -Market and plan	Combination of market and plan	Regulations, legal setting from the UK Government in order to execute consistent supervising. However, the oil companies are allowed to operate under capitalism for their profit seeking objectives.
(c) Property Rights -Control and income: Control biofuels national price through biofuels subsidies. Besides, the quality is also under control in order to comply the European Standard (both technical compliance and environmental conformity)	*Public limited company* (the privatised oil companies)	Regulations, legal setting from the UK Government to the oil companies to ensure that the biofuels commencement would achieve the initial objectives. The UK Government is collecting royalties and taxes from the oil companies.
(d) Incentives	Primarily Market	Financial incentive from the UK Government to the oil companies
(e) Public Choice	Regulated	Continuous management, monitoring and control from the UK Government, as well as the influence from the EU Government (under the single market principle).

Source: The Researcher utilised Gregory and Stuart (2004), FGTI analysis for the UK BRM

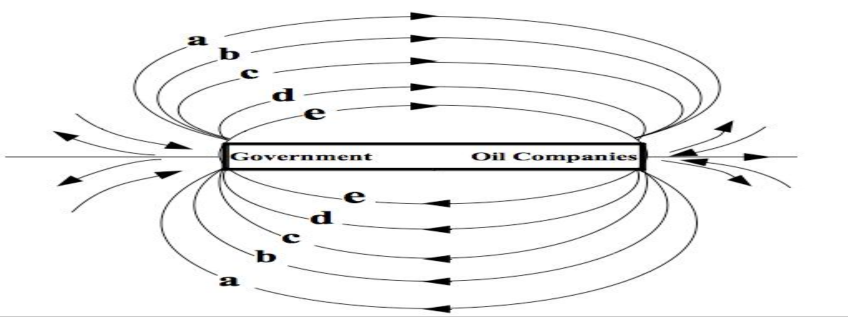

Figure 2.1.2: The UK BRM with FGTI Analysis
Indicators: a to e are Five types of institution linking the interactions between the governments and the oil companies
-The arrows at both ends represent relationship established between the government/oil companies and their respective stakeholders-such as social movements, environmentalists, roundtables and others.

Appendix 2.1.4 Roles of the Government in the Mixed Economy

According to Stiglitz (2000), while many economic activities are undertaken by private firms, others are undertaken by the government. In addition, the government alters the behaviour of private sectors through a variety of regulations, taxes and subsidies. This then generates another question, why the government intervenes in economic activities? One dominant view in the 18th century, particularly among French economists was that: the government should actively promote trade and industry. Advocates of this view were called mercantilists. It was partly in response Adam Smith-the founder of modern economics whom argued for a limited role of the government in economic activities. Smith attempted to show how competition and the profit motive would lead individuals in pursuing their own private interests as well as to serve the public interest. The profit motive would lead individuals, competing against one another, to supply the goods other individuals wanted. Only firms that produced what is wanted at a low possible price would survive.

Smith's ideas had a powerful influence both on the governments and on economists. Many of the most important 19th century economists: John Stuart Mill and Nassau Senior promulgated the doctrine known as laissez faire. In their view, the government should leave the private sector alone. It should not attempt to regulate or control private enterprise, as unfettered competition would serve the best interests of society. However not all 19th century social thinkers were persuaded by Smith's reasoning. The grave inequalities in income that they saw around them: the squalor in which much of the working classes lived and the social problems, unemployment that workers frequency faced had concerned them. While 19th century writers like Charles Dickens attempted to portray the plight of the working classes in novels, social theorists such as Karl Marx, Sismondi and Robert Owen, have developed theories that not only attempted to explain what they saw but also suggested ways in which society might need to be reorganised (Stiglitz, 2000).

Many attributed the evils in society to the private ownership of capital-what Adam Smith saw as a virtue they saw as a vice. Marx was certainly the most influential among those who advocated a greater role for the state in controlling the means of production. On one hand, private ownership of capital/unfettered free enterprise, while the other, the government control of the means of production. These contrary principles were to become a driving force for international politics and economics in the 20th century. Today, the countries of the former Soviet Union and the Eastern bloc are in the midst of a monumental transition to a market system. There is now widespread agreement that markets and private enterprises are at the heart of a successful economy, but the government has to play an important role to complement the market (Stiglitz, 2000).

The free market concept which operates based on the supply-and-demand mechanism has shown some critical evidences of market failures. Since the Great depression in 1925, to the current World Financial Crisis 2008-2012, there is a widespread view that market has failed in an important way. The public has put an enormous pressure on the government to do some corrective actions for the aftermaths. In responding to the economic crisis, various nations not only take a more proactive role in attempting to stabilise the level of economic activities, but also passed legislation designed to alleviate many of the economic related problems (Stiglitz, 2000).

Appendix 2.3.1 Branches of Renewable Energy Study

There are few branches of the RE study. The classification below, are a simplification to show some examples.

(a) Science:

-Bockris (2009) covers six sources of RE (solar, wind, waves, tides, geothermal and hydro). The feasibility in each case is analysed, stressing how the inexhaustible energies are all attain economic of scale after the collecting machinery has been paid for.

(b) Technology/Engineering:

-Bent (2007) provides strategies for the efficient conversion, transmission and storage; all forms of processes for RE such as geothermal, biological/liquid fuels, wave energy and photovoltaic.

-Twidell and Weir (2006) emphasis on science and engineering, the environmental benefits and impacts of each technology (solar, photovoltaic, wind, hydro, biofuels, wave, tidal, ocean and geothermal). His work is a numerate and quantitative text covering subjects of proven technical and economic importance that supported by modern applications and case studies.

-Kaltschmitt et al. (2007) present the physical and technical principles of utilising RE. The technologies of heat provision from passive and active solar systems, ambient air, shallow and deep geothermal sources, working together with electric generation from solar, wind, hydro and ocean energy.

-Wengenmayr and Buhrke (2008) give a concise overview in obtaining energy from RE (solar, geothermal, wind, waves and solar cooling). They also explain methods for energy storage, transportation and conversion to useful forms.

(c) Policy Study

-Assmann et al. (2006) provide a review of RE from world authorities including policy recommendations and best practice examples. An emphasis on policy and actions contributed from internationally renowned organisations to form an overview on the current status, impacts and the future potential of RE.

-Mallon (2006) outlines how RE can be promoted at political level, through encouraging the expansion of current market and the establishment of new industries.

There are various levels of policies:

-Defra. June 2009.

-Department of Energy and Climate Change. 2006.

-European Commission. January 2006

-Scottish Executive. 2006

-UNFCC. 2008

(d) Environmental Preservation

-Sorense (2004)'s work address different types of RE from technical descriptions of the devices that can be used to transform the energy into useful forms, to decrease the environmental impacts.

-Girardet and Mendonca (2009) treat the subject of climate change and RE as an ethical problem to be addressed on behalf of future generations. It has integrated much of the research and campaign work being done by the World Future Council: the work on feed-in tariffs, energy efficiency, sustainable agriculture, sustainable cities, future justice and the KidsCall campaign.

Appendix 2.3.2 Branches of Biofuels Study

There are few branches of the biofuels study. The classification below, are simplified to show some examples.

(a) Nature Science

-Lal and Stewart (2009) review the ecological consequences of biofuels and evaluate land use in the production of raw material for biofuels. Their work spotlights issues related to corn and cellulosic ethanol, and offers advice for achieving economic balance in the competition for arable land between food and biofuels.

-McBrewster et al. (2009) discuss types of biofuels which derived from algae, vegetable oils, soybean and seaweed. Besides, introduction of biogasoline, methanol, butanol from chemical and physics disciplines also being discussed.

(b) Technology/Engineering

-Soetaert and Vandamme (2009) discuss about the past accomplishments and future needs in developing biofuels industry. Their work highlights the significance of producing biofuels from biobased feedstocks and the technological developments in agriculture sector.

-Westermann et al. (2006) discuss the integration of Biomass Fermentation and Fuel Cells technology towards making fuels from wastes.

-Drapcho et al. (2008) describe the concepts, systems and technology involved in biofuels production.

-Demirbas's (2008) discusses the production of biofuels from wood, straw and household waste by using Fischer-Tropsch synthesis.

-Nag (2008) describes the latest refining processes and issues involved in producing fuel derived from recently living organisms/by-products. His work offers a discussion of theory and the actual experimental procedure used to economically manufacture biofuels on a commercial scale.

Appendix 2.3.3 The UK Wave Energy Programme

In 1974, the Labour Government launched a RE development programme, the wave power was initially seen as a front runner. When a Conservative Government came to power in 1979, it was evidently supportive. John Moore, the Energy Minister, commented in September 1980 “Whatever other problems wave energy researchers may face, lack of Government support will not be among them”(Moore,1980). The device teams in universities and elsewhere worked enthusiastically with some scale prototypes were tested in open water (Elliott, 2003d).

However, in 1982, views had changed and the wave R&D funding from £14 million to £11-12 million, following assessment from the Advisory Committee on Research and Development (ACORD) (Elliott, 2003d). The justifications for cutting was economic, due to the aftermath of US early 1980s recession, and aimed in saving public expenditure. Besides, the generation cost of 20p/kWh or more were mentioned, although the Energy Technology Support Unit (ETSU) reviewed, wave power put the likely cost of generation at 4p-12p/kWh. Even so, it concluded that “Wave power is likely to be economic only in future more favourable to RE technology” (ETSU, 1982). This story opened up some general issues, concerning the way technological innovation is handled (Elliott, 1995). The approach adopted in the UK government's initial programme on wave power (from 1976 onwards), was to establish a 2GW reference design target, and asked the wave power device learns to develop proposals for devices on that scale. Given that only small tank-tested models were available at that stage, it was quite a jump to try to come up with designs for full scale systems (Elliott, 2003d).

It has been argued by some innovation theorists that, large scale projects like this are inevitably inflexible. They do not allow an opportunity for piecemeal adaptation, incremental development feedback and learning from mistakes (Elliott, 2003d). In 1993, Audley Genus argued, the 2GW wave system design target reflected the UK energy establishment obsession with large scale units, as having all the hallmarks of inflexible technology. Thus, “lead times appear to be long, capital intensity high, unit size large and enormous investments of time, capital and other resources would have to be made before any learning about actual performance and improvements of these systems could be realised” (Genus, 1993). “This in turn made it very hard to come up with sensible cost estimates, and even harder to make sensible decisions about the future of the technology,” commented Stephen Sailer (Sailer, 1981).

There have been allegations that errors were made in ACORD's assessment, and some of the assessments conducted by external consultants were suppressed. Some critics suggested that there had been a pro-nuclear bias, which the way wave power had been treated. There were also concerns expressed about the stand of ETSU at the Atomic Energy Authority's Research. For its part, ETSU strenuously protested its independence. Other critics claimed that, the technology had been assessed at too early stage in its development (Elliott, 2003d).

As all party House of Commons Select Committee on Energy put it in 1984, the suspicion was that wave energy was effectively withdrawn before the race began (Select Committee 1984). There was considerable pressure from the Select Committee and from RE lobbyists for a reassessment. In 1989, a new review by ETSU was set in motion (Elliott, 2003d). However, in November 1992, the conclusions were similar: “Deep sea wave energy was still not seen as economic and inshore/onshore wave energy systems were not viewed much more favourably” (Thorpe, 1992). Of course very little new work had been done in the ten years since the 1982 decision to cut R&D financial support, this conclusion might not be surprising, because the 1982 decision certainly put a halt to work on deep-sea wave power (Elliott, 2003d).

It was not until a change of the government, in 1998 that the wave power issue was revisited seriously. Although not much new work had been done on wave energy in the UK, the political climate had clearly changed, in part because of growing concerns about climate change (Elliott, 2003d). A series of reassessments of wave energy was carried out. Initially, as part of the UK Technology Foresight programme, culminating in March 2001 with an admission by the Department of Trade and Industry (DTI) that the decision in 1992 to abandon wave energy was wrong: “With the benefit of hindsight, that decision to end the programme was clearly a mistake” (Ross, 2002).

Clearly, the fortunes of wave energy were changing, and the same happened in relation to tidal power. The favoured tidal technology now involving the extraction of energy via free-standing turbines mounted in the flow, rather than by large expensive and environmentally invasive tidal barrages (Elliott, 2003d). In May 2001, the House of Commons Science and Technology Select Committee commented: “Given the UK's abundant natural wave and tidal resource, it is extremely regrettable and surprising that the development of wave and tidal energy technologies has received so little support from the government” (Select Committee, 2001). Subsequently, ministers have increasingly keen to be seen as pro wave and tidal current projects, even though the level of funding that has emerged may not have reflected the rhetoric. So far only around £6 million has been allocated to new wave and tidal projects. Of course, the validity of these reassessments has still to be demonstrated. However, rather than trying to pick winners at an early stage, it seems wiser to allow a range of developments to proceed; especially since the level of expenditure at the R&D stage is relatively small (Elliott, 2003d).

The wave power story indicates that new technologies face major problems in getting accepted-there can be institutional biases and lack of vision (Elliott, 2003d). Given the uncertainties and the way wave power was treated in the UK, it is obviously hard to decide how to develop which new technologies. Much of the basic data is just not there, especially with novel technologies like renewables (Elliott, 2003d).

Appendix 2.3.4 The Wind Power Project

The second case study concerns the way wind power was developed, mainly on the approaches adopted in the UK, USA and Denmark. From the mid 1970s, the USA has adopted a high-tech aerospace approach with the emphasis on large/complex prototypes of the 2.5MW Boeing/NASA series. When the UK started its own wind programme in the early 1980s, a large 3MW machine (with the cost £17million) was built by the Wind Energy Group on the Orkney Islands. However, the large machines were not successful. There were some technical failures due to the great stresses on the giant blades, as they were too big, complex and expensive, pushing the technology too far too soon, which ended up these projects then have to be abandoned (Elliott, 2003d).

Around the world, commercial has shifted to smaller machines of around 300-400k rated power. Denmark had already taken a lead by emphasising relatively small, simple, robust machines, which subsequently proved to be a world beater. The Danish machines sold in great numbers to the USA and later to the UK (Elliott, 2003d). Part of the problem with the top-down, large scale, high-tech approach was, aerospace engineering concepts were not as relevant as expected when it came to devising systems that had to operate with varying wind loads[315]. As one US wind turbine engineer put it: “We were guilty of steady flow aerospace thinking and

315 Solely taking the most established aerospace and aviation technology, to venturing the wind power, has misjudged that: fundamentally both technologies are totally different, and also will be applied into a dissimilar surrounding; at least different in altitude and knots. In general sense, wind farms can only offer power intermittently, as we cannot expect the wind keeps blowing constantly from one direction. Therefore, solely a high-tech push with a simple thought: high-tech products guarantee commercial success could hardly match with the actual social acceptance.

largely did not appreciate the range and difficulty of the wind environment" (Stoddard 1986).

Interestingly, in recent years, machine sizes have increased dramatically with 1-2MW machines now being in use, and some even larger units are being developed. Incremental development seems to be the order of the day. Overall it seems that the initial focus on small machines, developed on an incremental "bottom-up" approach, has clearly triumphed over the top-down and high-tech approach which laid the bash for expansion (Elliott, 2003d).

Appendix 2.3.5 the UK Geothermal Programme

The UK's hot dry rock programme involved an experimental well at Camborne, was funded by the UK government. A double well system was created[316], but the initial results were disappointing: less power was produced than expected due to problems with the geology. Furthermore, establishing an efficient heat-extracting well configuration is difficult and expensive, even assuming the basic concepts are sound (Elliott, 2003d).

Nevertheless, the initial failure of the Camborne well led to a loss of confidence in the project, which by this stage had cost some £42 million. In 1994, the UK programme was halted, with the government concluding that the technology was not likely to generate electricity economically. Work on geothermal power has continued elsewhere in the world, but the Camborne project has been portrayed as a failure (NAO, 1994).

Appendix 2.3.6 Tidal Barrages in the UK

The UK tidal power is not a new concept due to the geographical advantage of the UK. The barrage has been operating successfully on the Ranee Estuary, France since 1968. However, obtaining finance for major tidal projects proved to be difficult in the UK (Elliott, 2003e). When the UK renewables research and assessment programme started in the mid 1970s, the tidal option was seen as significant, because the UK had some of the best sites in the world, notably the Severn Estuary.

A government-backed Severn Barrage Committee was set up to review the potential and reported back in 1981, confirming the results and indicated that a tidal barrage on the Severn Estuary would be technically feasible and could generate power at competitive costs once built. Although the Severn barrage scheme was seen as technically viable, the capital cost of building it would be very large-around £10 billion. The Severn Tidal Power Group-an industrial consortium consisting of many of the UK's leading construction and engineering companies has developed a proposal for an 11-mile long barrage, which could meet about 6% of the UK

316 The basic idea is to create a fissure system between the bottom ends of the two wells to act as means of collecting heat, with cold water being pumped down one well and hot water/steam emerging up the other. The fissure system is created by exploding a small charge at the bottom of the wells and this has to be done in exactly the right way. Technically, if the fissure system created allows water to pass through too easily, the flow through is too high and not enough heat is picked up. While if the artificial heat exchanger created by the fissure offers too much resistance to the water being pumped though, the flow rate is reduced and again not enough heat is absorbed. The fissure connections have to be just right and that depends on the precise geological nature of the strata (Elliott, 2003d).

electricity requirements (Department of Energy, 1989).

As it turned out, the main problem to face tidal power was the changed economic environment that emerged following the privatisation of the UK electricity industry in 1989-90. The Central Electricity Generating Board-the UK's nationalised utility, was broken up and the smaller private companies that replaced it were unlikely to be interested in a major project of this sort. A project on this scale might have been viable as a long-term publicly financed national investment, or via partnership arrangement with industry. However, following the privatisation of the electricity industry, it became clear that the government was not going to provide any further funding and the Severn barrage project was stalled. The private sector would be unlikely to want to take it on single-handedly, since in the economic climate of the time, it would be looking for much higher rates of return over shorter periods (Elliott, 2003e).

Appendix 2.3.7 Public Reactions to Wind Farm in the UK

By using the case study of the UK wind farm, Elliott (2003f) elaborates the actual scenario from the public reactions towards this project. It provides an example of the social needs, when seeking to new projects introduction, to be sensitive to local concerns and try to balance local environmental costs against global environmental benefits. New energy technologies are inevitably unfamiliar and their deployment can lead to public concern. There were some battles as the wind farm programme got underway with local oppositions.

The response from the environmental groups was mixed. Friends of the Earth maintained their long held support of wind power. So did the Labour Party affiliate Socialist Environment and Resources Association (SERA) and Greenpeace. The WWF and the Royal Society for the Protection of Birds were also supportive. However, some other major conservation groups, such as the National Trust were more critical of wind farms, while the Campaign for the Protection of Rural Wales, which initially adopted a supportive if critical stance, subsequently changed sides. So did the Ramblers Association, while the Welsh Tourist Board's 1994 “Tourism 2000” report expressed concern over the wind farm impact on tourism (Elliott, 2003f).

The Countryside Council for Wales (CCW) came out with a strong opposition line, arguing that: “While wind turbines are welcome as one of the sources of RE, the scale of their contribution to meet energy needs does not justify overturning established planning policies and safeguards.” Wind power projects tend “to threaten areas that CCW is charged to protect”. They also added that, there “should be a presumption against wind turbine development in areas of which close to sites with the benefit of statutory landscape designation status” (CCW, 1992). Besides, the Council for the Protection of Rural England (CPRE) also expressed its critical views. In 1991, evidence to the Department of Energy's Renewable Energy Advisory Group, CPRE called for greater scrutiny of projects and suggested that wind power should not be seen as a technical fix for the key political, social and economic problem (CPRE, 1991). Subsequently, Tony Burton from the CPRE told the Guardian (11 March 1994) that, while they were not opposed to wind power in principal, “The system is putting pressure to build wind farms in quite inappropriate places/remote landscapes that have been protected for decades" (Elliott, 2003f).

During 1993, objections emerged in Devon, Cornwall, Yorkshire and Wales. The UK's largest wind farm at Landinam, proved to be something of a turning-point has worsen the debate. There had been objections to its scale, on visual intrusion grounds. However in the event, it was noise that proved to be the major problem. Several local residents claimed to be suffering from major disturbance and there does indeed seem to be a significant noise problem for some residents in the valley below the ridge on which the 103 Mitsubishi machines are sited (Walker 1993). Even so, some colourful allusions have emerged. The Ecogen wind farm at Landinam was claimed by a resident to sound like a "twin-tub" washing machine. National Wind Power's wind farm at Llangwyrfon was alleged to sound like "an old wheelbarrow being pushed along continuously", while their Cold Northcott project in Cornwall was described as sounding like "a huge washing machine gathering speed to spin dry" (NATTA 1993).

Clearly, noise was the major issue for these people and this is a difficult matter to address. Visitors are usually surprised at how quiet wind farms sound, just a slight blade swish even close up, together with occasional gear train rumble. However, some machines are noisier than others. In some topographical situations these sounds can evidently be amplified by resonance effects within valleys. People's responses to the result can also vary. Some are very sensitive to low-grade background noise.

Certainly, once noise starts to be annoying, it can be detected even at very low levels. Some individual machines may have been particularly noisy during their run-in periods. The developers have been trying to respond to noise problems by installing noise insulation materials in the housing of the machines. More recently, the development of more advanced variable speed direct-drive machines has significantly reduced noise levels, since there are no longer any gear trains to rumble, and movement of the blades is better matched to the airspeed, so there is less noise from air turbulence (Elliott, 2003f).

However, less can be done by the designers and developers about visual intrusion and this has become the main problem. "Lavatory brushes in the sky" was how Sir Bernard Ingham described the wind farm near Hebden Bridge in Yorkshire-an allusion which has subsequently been repeated in various forms by the media. As the press secretary to Margaret Thatcher and public relations adviser to British Nuclear Fuels, Ingham has extensive media contacts and has been very outspoken on the wind farm issue. With the involvement of major public figures, the wind farm issue began to take on a national perspective and gained considerable national media coverage. Perhaps the key event was the setting up early in 1993 of a national anti-wind lobby group. Subsequently, a campaign against the proposal to site forty-four turbines at Flaight Hill near Hebden Bridge, has also attracted national media attention and the involvement of a number of celebrities, including pop star Cliff Richard and many notable literary figures. They wrote a letter, with sixty-two signatories, to the Times Literary Supplement, complaining about what they saw as an "assault on our literary and artistic heritage", given that the wind farm would be in Bronte country (Elliott, 2003f).

The press generally showed considerable interest in the local debate over wind farms. All of the major national newspapers[317] have carried reports with coverage increasing as objections mounted and the emphasis mainly on the negative side. The broadcast media also have generally adopted a fairly critical and in some cases, hostile approach. The BBC's "Country File" programme (24 April 1993) included a quite critical review, while BBC Radio 4's "You and Yours" programme (30 July 1993) presented a more or less unremittingly negative view. A Radio 4 "File on Four" programme (8 March 1994) was a little more hopeful, although it did suggest that the development of wind farms might turn out to be harder than the developers, and some environmentalists had initially hoped (Elliott, 2003f). The local press in the relevant areas carried regular news stories and features plus extensive letters. A rough survey of local press coverage in Wales during the period between March and December 1993, although in no way exhaustive, may indicate the general pattern: there were sixty-two news items, nearly all reporting "problems", and thirty-eight letters, with only eight being pro-wind (NATTA 1994).

Most of the objectors cited specific local problems: noise and visual intrusion, but some reflected wider conservation and preservation concerns, as well as fears about the impact on tourism. Some of the supporters complained about the lack of balance in the media debate. Ian Mays from the British Wind Energy Association complained to the Guardian (5 November 1993) that "a small but vociferous number people have generated a disproportionate amount of press coverage". Nevertheless, the campaigns clearly had some effect.

According to the Guardian (9 March 1994), Tim Eggar, the Energy Minister, is believed to be alarmed by the number of objections to proposed wind farms by groups who claim that their turbines impose noise and visual blight on the landscape. The Department of Trade and Industry (DTI) has been inundated with protests as part of a campaign at local and national level orchestrated (Elliott, 2003f). Mike Harper, the director of the British Wind Energy Association, asserted that "the controversy to date has largely revolved around misconceptions and misinformation[318] distributed by groups aiming to stifle wind energy development completely" (Harper, 1994).

Although "Not in My Back Yard" (NIMBY) type responses seem to predominate, there are also sometimes wider regional preservation and conservation concerns. Certainly, along with the issue of visual intrusion, wind projects might be expected to have some impacts on wildlife and the environment. The issue of bird strikes has not been seen as very significant in the UK (the Royal Society for the Protection of Birds has generally backed wind projects). Some damage can be done to the local ecosystem during construction and by the foundations for the concrete bases of the turbine towers. However, the wind turbines and their bases can be removed if

[317] The Times, Guardian, Independent, Telegraph, Observer, Financial Times

318 Certainly, there have been cases of misrepresentation and even disinformation. For example, the 10% fossil fuel levy has sometimes been cited by wind farm objectors as being the extra cost imposed on electricity consumers by the wind farms. In fact the bulk of this 10% is due to the support provided for nuclear power. Even given the initial artificially high level of support that had to be provided to wind projects as a consequence of the 1998 *Non-Fossil Fuel Obligation* deadline, the wind farm element so far has still only added around 0.1% on an average consumer's bills (Elliott, 2003f).

necessary, leaving the site unscathed.

Wind farms are not allowed in the statutorily defined Areas of Outstanding Natural Beauty and Sites of Special Scientific Interest, although some objectors have complained about wind farms spoiling the view from such locations. Some objectors accept the global argument (in relation to GHG emissions) but claim that wind farms could not help that much, so the local impact is not justified. For some others the central issue is what they see as "profiteering" by greedy developers who make use of the extensive subsidies, being concerned with the impact on the local environment. On the local proponents' side, strong support for wind farms is seen as part of a positive commitment to the future, with the threat of global warming often being cited, along with the dangers of nuclear power. Many supporters also say they like the look of the wind farms. Whilst those who do not, obviously feel strongly about it (Elliott, 2003f).

Appendix 2.4.1 Examples of Scholars in Risk Management

There are far more leading scholars in the field of risk management. The descriptions below are being simplified to show some examples.

-Pitblado and Turney (1996) analyse risks to investigate the industrial factors which leading to environment and financial implications.
-Courtney et al. (1999) look at technology competition in the future, using planning techniques and game theory to help decision maker to be prepared with business uncertainty.
-Phillips (2001) discusses market-oriented technology and develops the understanding of technology cycles, technology acquisition, technology management and technology policy. These understanding enable managers to find, acquire, develop, add value to technologies, and make a profit in the environment of short life cycles with rapid price reductions (for example in the electronics/semiconductor industries).
-Trott (2005) brings together the areas of innovation management and new product development in order to keep a strong emphasis on challenges face on innovation of management process.
-Bhattacharya's (2006) wait and see-is one of the strategies recommended to confront with business risk and uncertainty. Rather to confront the risk with enormous resources, the postponement would result better understanding of the risk, so that counteracting strategies could be applied.

Appendix 2.4.2 Examples of Managing Specific "Subject" of Risk and Uncertainty

There are few subjects of risk management. The classifications below are being simplified to show some examples.

(a) Managing risk on construction projects
-Institution of Civil Engineers (1998) focuses on the evaluation and controlling risks in major construction projects. It provides methods to enable a structured and consistent analysis of the resources implications of risk within projects to be carried out.

(b) Managing risk on general projects
-Aven (2008) suggests methodology for project planning, execution and use of risk analysis in various projects such as road tunnel construction, offshore installation, manufacturing production, cash depot and municipalities' projects. The methods include: quantitative risk analysis, financial risk analysis, probability calculus with statistics and reliability analysis.
-Cooper and Chapman (1987) are prone to engineering projects by using different approaches such as Common Information Model for risk analysis, subjective probabilities and economic risk evaluation.

(c) Managing risk in R&D projects
-Doctor et al. (2000) consider the issues of decision-making under uncertainty reference to R&D by using two techniques: the decision tree approach and the option pricing theory.

(d) Managing risk in Banking/Finance
-Saita (2007) presents the measurement of market risk and credit risk to improve a bank decision-making processes.
-White and Fan (2006) examine various approaches to incorporate measurement of risk into the appraisal of an international investment. They integrate existing theories, including the global capital asset pricing rule of financial theory and theories of strategy making; to show how risk should be incorporated into the present value formula to produce a clear decision rule.
-Dale (1996) focuses on "contrasting approaches" to the regulation of investment firms in the major financial centres, while highlighting the underlying policy differences in the countries concerned.
-Korath (1998) uses auditing technique to identify risk factors, and allocate resources to deal with risk and uncertainty.
-Banks' (2009) work presents an in-depth discussion of the nature and consequences of financial disasters; as well as the pragmatic solutions that should be considered to deal with such crisis.
-Moore (1999) advocates a systematic approach to risk arbitrage techniques that work in today′s market. Because of the growth in hedge funds and the changing nature of the merger and acquisition, business has been affected.

(e) Managing risk in Insurance
-Culp (2006) details the structured finance and insurance solutions which provide alternatives for managing today's corporate risks.

Appendix 2.5.1 Examples of Scholars in Individual Risk Context
There are far more leading scholars in the individualist risk context. The descriptions below are being simplified to show some examples.
(a) Personal Circumstances
-Adams (1995) addresses cultural construction of pollution and road safety.
-Green (1997) discusses accidents, rationality and the emergence of accidents, also preventing accidents.
-Barton's (2006) work helps with the planning and management of outdoor activities for young people. He explores the issues that need to be considered when

developing/implementing outdoor policies and procedures, for Health and Safety Officers to improve their understanding of adventure education.

(b) Corporate

-Chapman's (2006) Enterprise Risk Management discusses the way businesses approach risk. As the economy becomes globally oriented, risk and uncertainty such as currency fluctuations, human resources in foreign countries, cultural differences, evaporating distribution channels, bureaucratic corporate governance and unprecedented dependence on technology are just a few of the risk and uncertainty which businesses cannot afford to let them remain unidentified.

-Samociuk et al. (2010) discuss about fraud risks, either in any organisation/business unit where managers would like to add value by building fraud resistance into their organisation. This is to demonstrate to shareholders, regulators/other stakeholders that they are capable in managing fraud risks for prevention measures, rather than just reacting to incidents.

Appendix 2.5.2 Examples of Scholars in Societal Risk Context

There are far more leading scholars in the risk management. The descriptions below are being simplified to show some examples.

-Luhmann (1991) discusses protest movement, demands on politics, risk in the economic system and risky behaviour in an organisation. He shows how the modern society, with politics, law, science and economy react to the hazardous situations.

-Doughlas (1992) addresses scientist disagreement between science versus policy and border issues in America. Her findings concluded that, any analysis of risk perception that ignores cultural and political bias is worthless. This is because, the study of risk needs a systematic framework of political and cultural comparison.

-Doughlas (1994) discusses risk and justice, AIDS, British and Swedish labour market, autonomy versus opportunism and the issue of women priests. She argues that the prominence of risk discourse will force upon the social sciences of rethinking and consolidation, which will include the anthropological approaches studied. A culture is viewed as a way of life which standardises concepts and values. It is held steadily by the institutions in which it is articulated. Hence, questions of autonomy, credibility and gullibility, the social origins of wants and the recognition of distinctive thought styles are at present only beginning to be treated systematically in a society.

-Doughlas (2002) reveals the cognitive psychology treats decision-making as a private personal act, but in real life dangers are presented in standardised forms which pre-code the individual's choice. This is particularly obvious since the gap has been increasing between those who participate in the decision-making and those who are excluded from the process-but who nevertheless have to bear the consequences of the decisions made.

-Leiss and Chociolko (1994) study roots of disagreement/conflicts and how to manage risks.

Both of them look into controversies over how to manage health and environmental risks, trying to determine what is in the public interest at the heart of these disagreements. Their findings explain that controversies arise, because many participants try to avoid full responsibility for the consequences of the risk-taking they advocate.

-Lupton (1999) examines why risk has come to such prominence, and how risk has been constructed over time from pre-modernity to the later modern era. She covers a wide range of issues including discusses cultural perspective on risk perceptions that emphasising the importance of sociocultural beliefs on risk.
-Lupton (2000) uses the recent social and cultural theory. She reflects the fact that, risk has become integral to contemporary understandings of self-hood and the social relations with a diverse range of topics including: drug use, risk in the workplace, fear of crime, pregnant embodiment, the social construction of danger in childhood, anxieties about national identity and the relationship between risk phenomena and social order.
-Boyne's (2003) work explores the measurement of risk in its social context, the idea that the mass media or the political opposition always exaggerate risk, and the reliability of the risk expert.
-Tulloch and Lupton (2003) examine how people respond to, experience and think about risk as part of their everyday lives. Their work bridges empirical research and sociocultural theory, examines how people define risk and what risks they see as affecting them from the issues of immigration, unemployment, family life and contemporary crimes.
-Ericson and Doyle (2003) examine how decisions about risk and uncertainty relate to moral principles and ethical conduct.
-Sunstein's (2004) work is based on the global concern/interest of risks to safety, health and the environment impacts. He discovers that, in general too much of the time we fear for the wrong things. Sometimes we make the situation even worse. Rather than investigating the facts, we respond to temporary fears. The result is then, a situation of hysteria, neglect with unnecessary illness and death. Sunstein explains the sources of these problems and explores what can be done about them. He shows how individual thinking and social interactions lead us in foolish directions. To resolve this, he proposes a more sensible system of risk regulation, embodied in the idea of a cost-benefit state which could save many resources and lives.
-Kasperson and Kasperson (2005) acknowledge that we are living in a "risk society" where the identification, distribution and management of risks-from new technology adoption and the subsequent environmental impacts are crucial to the individual and social existence.
Volume I collects their work on how risks are communicated among different stakeholders, including local communities, corporations and the larger society. They analyse the problems of lack of transparency and trust, and explores how minor effects can be amplified and distorted through media and social responses. The final section investigates the difficult ethical issues raised by the unequal distribution of risk depending on factors such as wealth, location and genetic inheritance with examples from worker and public protection, transporting hazardous waste and widespread impacts such as climate change.

Volume II centres on the analysis and management of risk in society and in international businesses. Their work clarifies the structures and processes for managing risks in the private sector and the factors that produce/impede effective decisions. The authors demonstrate that corporate culture is crucial in determining risk management, where they analyse the transfer of corporate risk management systems from industrial to developing countries through the force of globalisation.

Some of the issues being discussed are Bhopal disaster, industrial crisis, technology transfer, hazards in developing countries and environmental degradation.

-Titterton (2005) emphasis on risks and health issues on social welfare. His work offers an innovative model for risk assessment and management, examines the dilemmas frequently faced by professionals working with elderly, the homeless, people with physical/learning disabilities and people with mental illness.
-Smith and Petley (2009) establish the basic concepts of hazard, risk, vulnerability and disaster. The critical attention is given to the scale of disaster impact and the various strategies that have been developed to minimise the impact of damaging events.

Appendix 2.5.3 Redefining Systemic Risk
Presentation in a table form could clearly demonstrates, the characteristic, the causal factors and the implications of systemic risk.

Table 2.5.1 Characteristic, Causal Factors and Implications of Systemic Risk

Characteristics	Causal Factors	Implications
-Systemic risk is volatile/evolving risk. It involves a high degree of uncertainty because it is new/unpredictable, and it does not have a track record which can be used to estimate and anticipate the likely probabilities of occurrence and losses. -It is complex, and beyond any particular/single party's capability to control. Hence, combined strategies from related stakeholders are needed in order to provide more comprehensive solutions to counteract it.	-Natural events, human action' economic, social, technological developments and policy driven actions, mismanagement and failure of technological design. -Modernisation of society which interwoven with complicated technology applications and mutual dependence, putting the basic human needs like air, food, water, shelter, security, financial, transport, energy, health, employment, environment etc. under vulnerability. -It might also be caused by interests, motives of stakeholders in maximising gains to satisfy their benefits.	-Large implication on social, environment, economic, politic structures, and may be prolonged with long-term effects which pervades to national/international level.

Source: Summarised by the Researcher

The descriptions of systemic risk above are wide and general, in order to depict the characteristics, possible causal factors and implications for a general, yet comprehensive understanding, without implying a particular consensual orthodoxy, clear boundaries or claims of ownership to the field. Much of the strength in this area lies in the diversity of work which it encompasses and the future works would enrich the concept and context of systemic risks.

Appendix 2.6.1 Examples of Different Functions under Risk Management
There are far more leading scholars in different functions under risk management. The descriptions below are being simplified to show some examples.

(a) Risk Assessment
Hester and Harrison (2006) raise concern over the adverse environmental consequences from the use of chemicals; which led to a steady increase in national activity towards greater regulation, as well as voluntary agreements with manufacturers for risk management of certain products. Their work reviews the current framework of legislation for the regulation of chemicals in the UK and reports expert views on both the current situation and future developments. There are many scientific and technical issues have been addressed. These include pollution risk appraisal, cancer risk assessment, environmental risk assessment, human health from land filling and aquatic risk assessment for pesticides.

(b) Risk Perceptions
-Baruch, et al. (2009) study investigate psychometric procedures were used to elicit quantitative judgements of perceived risk, acceptable risk and perceived benefit for each of 30 activities and technologies.
-George, et al. (2009) argue, most of the current theories of choice under risk and uncertainty are cognitive and consequentialist. They assume that people assess the desirability/possible outcomes of choices, integrate information through expectation-based calculus to arrive at a decision.
The work proposes an alternative theoretical perspective-the "risk as feelings" hypothesis which highlights the role of emotions affecting the moment of decision-making. Drawing on research from clinical, physiological and other sub-fields of psychology, the finding shows that emotional reactions to risky situations often diverge from cognitive assessments of those risks. When such divergence occurs, emotional reactions often drive behaviour.
-Renn (2008a) reveals, a vast majority of studies on risk perception and concerns tends to show, most of the worries are not related to blatant errors/poor judgement, but to divergent views about the tolerability of remaining uncertainty, short-term versus long-term impacts, the trustworthiness of risk managing agencies. This is why the risk governance framework emphasises the need for comprehensive risk understanding.

(c) Risk Communication
-Morgan, et al. (2001) advocate, people today make decisions about health, safety, and environmental risks. To make sound choices they need to get good information. As such, information has to be carefully selected and clearly presented. Their work provides a systematic approach for risk communicators and technical experts, hoping to serve the public by providing information about risks. The procedure uses approaches from risk and decision analysis to identify the most relevant information. Then the procedure uses approaches from psychology and communication theory to ensure that it is understood.
-Lundgren and McMakin (2008) work addresses, because health, safety and environmental risks take centre stage in our daily living, communicating risk information can be a great challenge. As such, risk communication must be targeted, understandable and effective without inadvertently provoking hostility and mistrust.

The book is divided into five parts. Part I provides background information to understand basic theories and practices of risk communication. Part II explains how to plan a communication effort. Part III describes how to put risk communication into action. Part IV discusses how to evaluate risk communication efforts, including techniques to measure success. Part V discusses communicating risk during and after a health/environmental emergency, from bioterrorism attacks to mad cow disease.

(d) Risk Management
Office of Government Commerce (2007) advocates, every organisation must find the right balance between opportunities and threats in managing its risks, across organisational activities (from strategic, programme/project to operational perspectives). The work provides practical approaches, which offers a structured and effective framework for risk management. Its aim is to help organisations to achieve their objectives by first identifying the risks, and then choosing the right response to the threats and opportunities that are created by risk and uncertainty.

Appendix 2.6.2 Examples of Quantitative Risk Management
-Korath (1998) applies auditing concept to identify risk factors and allocate resources (through decision-making) to high risk areas. This approach increases the probability of detecting misstatements that caused by errors and irregularities.
-McNeil et al. (2005) concentrate on four categories of risk: financial markets, consumer markets, credit and operational risks. Their work draws on diverse quantitative disciplines (mathematics, statistics and econometrics) which discusses on loss distributions, risk measures, risk aggregation and resources allocation.
-Vose (2008) provides a comprehensive guide for risk analyst/decision maker in order to solve real world risk problems. The analysis is based on the quantitative approach, using Monte Carlo simulation and numerical techniques. These techniques are aimed to produce an accurate risk analysis model, and offers general/specific modelling to risk problems. A wide range of solved examples is used to illustrate the effectiveness of these two techniques, and how it can be put together to make the best possible risk-based decisions.

Appendix 2.6.3 Four Components of Pre-assessment
The pre-assessment would vary, depend upon risk source and risk target. However, it does not mean that pre-assessment is always taken before. Rather they are logically located at the forefront of assessment and management. Pre-assessment can be viewed as an opportunity for early prevention of more serious threats. Careful framing, warning, screening and selection of rules are essential for reducing overall risk by preventing decision makers from neglecting key risks/concerns (shown in Table 2.6.1).

Table 2.6.1: Four Components of Pre-assessment

Four Components	Indicators
(a) Problem framing -Different perspectives of how to conceptualise the issue	-Dissent/consent on the goals of the rule selection -Dissent/consent on the relevance of evidence -Choice of frame (risk, opportunity, fate)
(b) Early warning -Systematic search for new hazards	-Unusual events/phenomena -Systematic comparison between modelled and observed phenomena -Novel activities/events
(c) Screening -Establishing a procedure for screening hazards/risks, then determining an assessment and management route.	-Screening in place? -Criteria for screening: hazard potential, persistence, ubiquity, etc. -Criteria for selecting risk assessment procedures for: known risks, emergencies, etc. -Criteria for identifying and measuring social concerns
(d) Scientific conventions for risk assessment and concern assessment -Determining the assumptions and parameters of scientific modelling/evaluating methods/procedures for assessing risks and concerns.	-Definition of no-observed-adverse-effect-levels (NOAELs) -Validity of methods and techniques for risk assessments -Methodological rules for assessing concerns

Source: Renn (2008b) pp. 51.

Appendix 2.6.4 Complex, Uncertain and Ambiguous of Risk Appraisal

Complexity refers to the difficulty of identifying and quantifying causal links between a multitude of potential causal agents and specific observed effects. The nature of this difficulty may be traced back to interactive effects among agents (synergisms and antagonisms), long delay periods between cause and effect, inter-individual variation and intervening variables. Risk knowledge therefore can be classified according to the degree of complexity of the assumed causal relationship.

Uncertainty refers to a lack of clarity over the scientific/technical basis for decision-making. It is essential to acknowledge that human knowledge is always incomplete and selective, thus contingent upon uncertain assumptions, assertions and predictions (Funtowicz and Ravetz, 1992; Laudan, 1996; Bruijin and ten Heuvelhof, 1999).

Interpretative and normative ambiguity arises when differences exist in how actors or stakeholders value some input or outcome of the system as a result of divergent or contested perspectives on the justification (Stirling, 2003). In relation to RG, it is understood as "giving rise to several meaningful and legitimate interpretations of accepted risk assessments results". It can be divided into interpretative ambiguity (different interpretations of an identical assessment result) and normative ambiguity (different concepts of what can be regarded as tolerable). A condition of ambiguity emerges where the problem lies in agreeing on the appropriate values, priorities, assumptions and boundaries to be applied to the definition of possible outcomes (Renn, 2008c).

Appendix 2.6.5 Tolerability and Acceptability of Risk

The distinction between tolerability and acceptability can be applied to a large array of risk sources/events. This could be demonstrated through a risk diagram, with probabilities on the y-axis and extent of consequences on the x-axis (Figure 2.6.1). This is also known as the "traffic light model", representing acceptable risk in green, tolerable risk in amber and intolerable risk in red. To draw the line between intolerable and tolerable; as well as tolerable and acceptable is one of the most difficult tasks of RG. However, difficult still possible to be implemented, provided the judgement on acceptability versus tolerability is contingent upon making use of a variety of different knowledge sources (Renn, 2008d).

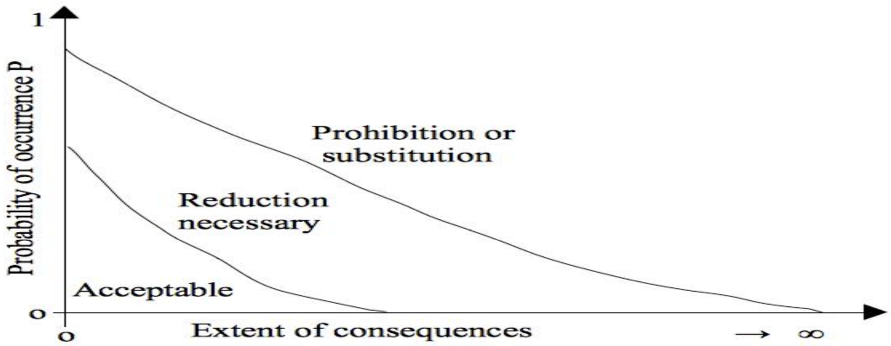

Figure 2.6.1: Acceptable, Tolerable and Intolerable Risks
Source: Renn, 2008d. pp.150.

(a) Acceptable situation

The risks are so small, even regarded as negligible that any risk reduction effort is unnecessary. However, risk-sharing via insurance and further risk reduction on a voluntary basis present options for action that can be worthwhile pursuing even in the case of an acceptable risk.

(b) Tolerable situation

The risks need to be reduced/handled in other ways within the limits of reasonable resource investments. This can be done by private actors, public actors or both public-private partnerships.

(c) Intolerable situation

Either the risk source needs to be abandoned/replaced; or in cases where that are not possible to abandon, vulnerabilities need to be reduced and exposure restricted. Renn (2008d) adds, the traffic light model might represent an oversimplification. However it reflects the actual need for a judgement at the end of an evaluation process. This allows for these alternatives at a particular time: either to take no management action[319], or to initiate actions for mitigation. The model emphasises this evaluation be made as transparent as possible to all interested stakeholders. The organisations which responsible for this judgement should have the skills, assets, background knowledge and the sensitivity to arrive at an informed, balanced and fair judgement.

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319 allows for doing additional research, collecting the input necessary to re-evaluate the risk at a later time.

On the collective/societal level, risk evaluation should consider positive external effects: the labour market, the competitiveness of an economy and the effects on social. The RG framework anticipates the need for deliberation during risk evaluation. This is the point which risk acceptability and tolerability are addressed (Table 2.6.2); and the likely benefits to society-whether in whole/in part, must be included in the balancing procedure. The delicate nature of balancing benefits and risks is also the reason why, in the process of risk evaluation, all relevant stakeholders need to convene for making the necessary trade-offs between conflicting objectives and values (Renn, 2008d).

Table 2.6.2: Tolerability versus Acceptability Judgement

Assessment Components and Definitions	Indicators
(a) Risk characterisation -Collecting and summarising all relevant evidence necessary for making an informed choice on tolerability versus acceptability of the risk; and suggesting potential options for dealing with the risk from a scientific perspective.	Risk profile: -Risk estimates -Confidence intervals -Uncertainty measures -Hazard characteristics -Range of legitimate interpretations -Risk perceptions -Social and economic implications
(b) Risk evaluation -Applying societal values and norms to the judgement on tolerability versus acceptability, consequently determining the need for risk reduction measures.	Judging the severity of risk: -Compatibility with legal requirements -Risk trade-offs -Effects on equity -Public acceptance Conclusions and risk reduction options. Suggestions for -Tolerable risk levels -Acceptable risk levels -Options for handling risks -Choice of technology -Potential for substitution -Risk-benefit comparison -Political priorities -Compensation potential -Conflict management -Potential for social mobilisation

Source: Renn (2008d) pp. 155.

Appendix 2.6.6 Six Classical Decision Theory for Risk Management

Hammond, et al. (1999), Morgan (1990; 1995), Keeney (1992), Aven and Vinnem (2007) discussed and provided new inputs on six classical decision theory. These six steps follow a logical sequence, yet could be arranged in different order, depending upon both situation and circumstance. In fact the steps are not as a linear progression, but as a circle forming an iterative process which reassessment phases are intertwined with emerging options. Table 2.6.3 summarises the steps of RM (Renn, 2008e).

(i) Identification and Generation of Risk Management Options

Generic RM options include risk avoidance, risk reduction/mitigation, risk transfer and self-retention. Avoiding a risk means selecting a path that does not touch on the risk (like abandoning the development of a specific technology). Reducing a risk is taking actions to eliminate a certain risk of its implications. Risk transfer deals with ways of passing the risk on to a third party. Self-retention means taking an informed decision to do nothing about the risk, but to take full responsibility both for the decision and consequences occurring thereafter (Renn, 2008e).

(ii) Assessment of Risk Management Options Regarding to Predefined Criteria

Each of the options will have desired and unintended consequences, relate to the risks that they are supposed to reduce. Hence, measuring management options against two criteria “desired” and “unintended impacts” may create conflicting messages and results. Many measures that prove to be effective may turn out to be inefficient, or unfair to those who will be burdened. Other measures may be sustainable, but not accepted by the public/stakeholders. What appears to be efficient in one country may not work at all in another country. Therefore risk managers are advised to make use of the many excellent guidance documents on how to handle risk trade-offs, and how to employ decision/analytic tools for dealing with conflicting evidence and values (Viscusi, 1994; Wiener, 1998; van der Sluijs et al., 2003; Goodwin and Wright, 2004).

(iii) Evaluation of RM Options

This step integrates the evidence on how the options perform in terms of predefined evaluation criteria, with a value judgement about the relative weight that each criterion should be assigned. Ideally, the evidence should come from experts and the relative weights from politically legitimate decision-makers. Thus, the evaluation of options is conducted in close cooperation between experts and decision-makers. This is the step where direct stakeholder involvement and public participation are important (Rowe and Frewer, 2000; OECD, 2002).

(iv) Selection of RM Options

Once the different options are evaluated, a decision has to be made as to which options are selected and which rejected. This decision is obvious if one/more options turn out to be dominant, otherwise, trade-offs have to be made that require legitimisation (Graham and Wiener, 1995). A legitimate decision can be made on the basis of formal balancing tools (like cost-benefit analysis), by the respective decision-makers or in conjunction with participatory procedures (Renn, 2008e).

(v) Implementation of RM Options

It is the task of RM to oversee and control the implementation process. In many cases, implementation is delegated while outcomes are monitored (Renn, 2008e).

(vi) Monitoring of Option Performance

This refers to the systematic observation of the effects (from the options made) once they are implemented. The monitoring system should be designed to assess intended/unintended consequences. Often, a formal policy assessment study is issued in order to explore the consequences of a given set of RM measures on different elements of what people value. In addition, to generate feedback, the monitoring phase provides new information on early warning signals for both new risks and old risks viewed (Renn, 2008e).

Table 2.6.3 Summary of Generic Components of RM

Management Components and Definitions	Indicators
(i) Option generation -Identification of potential risk handling options, risk reductions, prevention, adaptation and mitigation, as well as risk avoidance, transfer and retention.	-Technical standards and limits -Performance standards/rules -Restrictions on exposure/vulnerability -Technical prescriptions -Governmental economic incentives -Third party incentives -Compensation schemes -Insurance and liability -Cooperative and informative options -Voluntary agreements -Information/education
(ii) Option assessment -Investigation of the impacts of each option (economic, technical, social, political)	-Effectiveness -Efficiency -Minimisation of external side effects -Sustainability -Fairness -Political and legal implementation -Ethical acceptability -Public acceptance
(iii) Option evaluation and (iv) selection -Evaluation of options	-Assignment of trade-offs -Incorporation of stakeholders and the public
(v) Option implementation -Realisation of the most preferred option	-Accountability -Consistency -Effectiveness
(vi) Monitoring and feedback -Observation of the effects of implementation Ex-post evaluation	-Intended impacts -Unintentional impacts -Policy impacts

Source: Renn (2008e), pp.175.

Appendix 2.6.7 Risk Management Strategies Based on Risk Characteristics

Table 2.6.4: Risk Characterisation and Implications for Risk Management

Risk Characterisation	Management Strategy	Appropriate Instruments	Stakeholder Participation
(a) Linear risk problems	Routine-based (tolerability/acceptability judgement) (risk reduction)	-Applying conventional decision-making *Risk-benefit analysis *Risk-risk trade-offs *Trial and error *Technical standards *Economic incentives *Education, labelling and information *Voluntary agreements	Instrumental discourse
(b) Complex risk problems	Risk-informed (risk agent/causal chain)	-Characterising the available evidence Expert consensus-seeking tools *Delphi/consensus conferencing *Meta-analysis *Scenario construction Result fed into routine operation	Epistemic discourse
	Robustness-focused (risk-absorbing system)	-Improving buffer capacity of risk target through: *Additional safety factors *Redundancy and diversity in designing safety devices *Improving dealing capacity *Establishing high-reliability organisations	
(c) Uncertainty-induced risk problems	Precaution-based (risk agent)	-Using hazard characteristics: persistence and ubiquity as proxies for risk estimates Tools include: *Containment *ALARA (as low as reasonably achievable) * ALARP (as low as reasonably practicable) *BACT (best available control technology)	Reflective discourse
	Resilience-focused (risk-absorbing system)	-Improving capability to deal with surprises *Diversity to accomplish desired benefits *Avoiding high vulnerability *Allowing flexible responses *Preparedness for adaptation	
(d). Ambiguity-induced risk problems	Discourse-based	-Application of conflict-resolution methods, for reaching consensus or tolerance for risk evaluation results and management option selection *Integration of stakeholder involvement in reaching closure *Emphasis on communication and social discourse	Participatory discourse

Source: Renn (2008e), pp.182-183.

Appendix 2.7.1 Elements of Regime Context and Content

(a) Type of Risk

Type of risk involves the inherent features of the hazard. It includes risk source, cause, how familiar risk event is, how it could be quantified such as-the probability of occurrence, timing, its impacts/consequences (Hood et al., 2004b).

(b) Public Preferences and Attitudes

This is related to the public perception on risk event. In a democratic society, the government is expected to deal with public risk, while citizens should be kept fully informed by their governments. The reactions are due to the government's perception of public opinion. This may be determined by the source of information such as opinion polls, the media, constituents and lobbyists (Andreeva, et al., 2009). As such, risk event vary in terms of the level of overall public concern, varying from high anxiety to deep apathy, how "hot" or "cold" they are in media coverage, and how the political authority would shaped socioeconomic communication either at "above"[320] or "below" the line content[321].

According to Hennessy (1990), interest groups[322] are with legitimate purposes wholly in the public interests. These different groups have their own agenda to be lobbied, and from this would generate their own reactions to public risks. Besides, lobbying brings more information into the system. Yet, the question arises whether it is resonant with political agenda or with public concerns? Explained by Andreeva, et al. (2009), the views which these interest groups offer, may be supporting the regulators, or in conflict with the government's view. Besides, in practice, they usually use the media or opposition parties as a vehicle to increase their pressure on the government. This creates a potential of uncertainty which might lead to heightened public concern and escalation of the public risk. Thus, regulation in a context of media silence and public apathy is very different from regulation conducted in the heated atmosphere of high media attention and public salience.

(c) Organised Interests

The risk event is varying in who/what creates and who is exposed to the hazard (victim). This leads to a question: "How is risk distributed between the creator and the impactor?" Such distributional questions are often central to risk regulation, since they raise issues of relative power on the group affected (Hood et al., 2004b).

(d) Size

This is broadly how much regulation is brought to bear on any risk. Size can be conceived in two ways: aggression[323] and overall scale of investment-which goes into the regime as direct tax-financed state spending. Regulatory size is at issue for those who are concerned about the balance between the state and the market, the threshold of risk toleration, and the degree of "anticipationism" in risk regulation

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320 Above the line refers to the actual content of the message (Andreeva et al., 2009).

321 Below the line refers to the more subjective and implicit communication designed to arouse more positive feelings towards the message sender (Andreeva et al., 2009).

322 lobbyists, social movements, public representatives and environmentalists.

323 Denoting the extent of risk toleration in standards and behaviour-modification; how far regulators go in collecting information about the risk (Hood, et al., 2004b).

(Hood et al., 2004e).

(e) Structure

It refers to the way regulation is organised, institutional arrangements that are adopted and the resources invested. Structure can be conceived in two ways: the extent which regulation involves a mix of public[324] and private sector; and how densely populated the regulatory space/policy community is by separate institutions (Hood et al., 2004b).

(f) Style

Style denotes the operating conventions and attitudes of those involved in regulation, and the formal/informal processes through which regulation works. Style can be conceived in two ways: familiar in socio-legal discussions [325], and the attitudes/beliefs of the various regulatory actors, in particular the pursuit of policy objectives. Although style may seem less tangible than size and structure, it is the central issue for those who see culture and attitudes as all important in the way regulation works (Hood et al., 2004b).

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324 In the UK, there are a number of interacting bodies: Westminster Parliament, Scottish Parliament, Welsh Assembly, Northern Irish Assembly and Local Authorities. There are also a number of institutions outside UK: UN, European Parliament. Thus, the political structure of the UK government is mixed, comprises of different levels of authority (Andreeva, et al., 2009).

325 It is the question of how far the operation of regulation is rule-bound, and how far it is based on direct command and control approaches (Hood, et al., 2004b).

Appendix 2.7.2 Disaggregating Regime Context and Content

Table 2.7.1: Disaggregating Regime Context and Content

Basic Elements	Second disaggregation	Third disaggregation
Regime Context		
Type of risk	-Degree of residual risk: risk which has not handled by other regulatory system, or arise under situation without regulation -Degree of market and tort law, failure	-Overall level of risk: probability and consequence -Certainty, disputed and uncertain nature of risk -Degree of information failure -Degree of opt-out failure
Public preferences and attitudes	-Media/public salience -Degree of uniformity or coherence of opinion	-Media salience -Mass public opinion salience -Degree of consensus -Degree of coherence
Organised interests	-Presence of dominant organised groups -Degree of mobilization of affected stakeholders	-Degree of business capture -Degree of professional capture -Level of mobilization -Level of militancy
Regime Content		
Size	-Policy aggression: how active regulation is, how much risk is tolerate-able and how much change is aimed at -Overall regulatory investment: the overall scale of resources going into regulation from all sources	-Extent of policy proactivity -Degree of policy ambition -Level of money costs -Level of time, skill and attention
Structure	-Non-state share of regulatory resources: how regulatory costs are distributed between the state and regulatees -Organisational fragmentation and system complexity: interfaces with other regimes	-Level of compliance costs -Level of third-party contributions -Number and density of regulator organisations -Degree of jurisdictional overlap and system complexity
Style	-Rule-orientation: the overall extent to which regulation is governed by rules -Regulatory zeal: the extent to which regulators are ‘zealots’ for policy positions rather than neutral and detached in their approach	-Density of formal regulatory rules -Degree of operational rule-following -Extent of regulator commitment to policy -Extent of regulatory lifetime ‘vocation’

Source: Hood, et al., 2004b. pp.34.

Appendix 2.7.3 Different Opinions between Various Groups in GM Products

Table 2.7.2 Different Standpoints on GM Food Discourse

Underpinning logic behind position taken	Types of GM Food Discourses
Ideological Choice (Because of)	Environmental Movement: Irresponsible manipulation of nature for corporate profit and unknown health risks. Long-term effects cannot be measured today. Call for more organic foods. Hunger from misdistribution, inadequate supply of food in the world.
Systems Vindication (Because of)	Industry Economists: Increase the overall food supply and protect the environment from dangerous pesticides. Biotechnology should be seen as part of ecological modernisation. Increased food supplies will help feed the hungry in the Third World.
Situational Validation (Because of)	Medical and Nutrition Experts: Organise farms need special protection again seed contamination. There is also a need for protective labelling of GM foods for people with allergies. Farmers in developing countries are unable to buy the modified seeds and compete with those who can, thus leading to increases unemployment and poverty.
Warrant (Since)	Risk Analysts: Measured again acceptable safety standards no harmful effects are found
Model for reason for specific groups	Data--Technical Verification--Conclusion

Source: Fischer (2004).

Table 2.7.3 illustrates the differing opinions that taken by protagonists in the debate on genetically modified (GM) foods. Environmentalists take an ideological stand, reject GM foods for the reasons of public health. The industrial economists vindicate the situation of increasing food supply that may accrue. Health and Nutritional Experts need reassurance about aspects of the introduction of the GM foods. Risk Analysts may view the problem as an issue of measurement of the risk, and an assessment of whether the risk level is acceptable. Hence the difference between these individuals is not the estimates of the risks, but the values and belief systems which are dissonant amongst the protagonists (Andreeva et al., 2009).

Appendix 2.7.4 Various Models for Public Risk

The threshold is the level at which the risk enters the public agenda. By studying

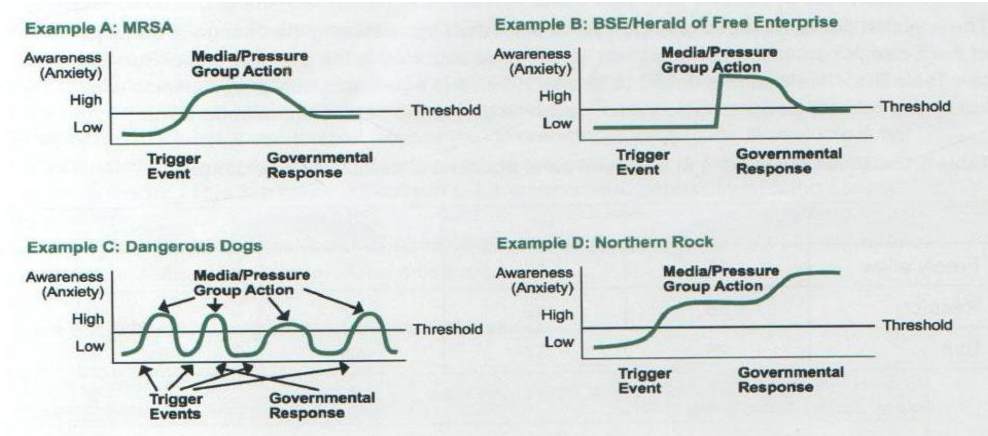

Figure 2.7.1 Public Risk and Time
Source: Andreeva, et al. (2009), pp.15.

four cases, it is easier to see the difference in the threshold levels. In the case of Methicillin Resistant Staphylococcus Aureus (MRSA) (example A), there has always been a backdrop of the infection. It will not be possible to eradicate MRSA totally. However, over time, it is hoped that it will fall to controllable/manageable levels. Events, such as Bovine Spongiform Encephalopathy (BSE)[326] (example B), tend to be more abrupt and rising quickly in public concern. This caused hard prediction and forecast of its impacts.

Some events repeat over time, such as the risk of dangerous dogs (example C), either in exactly the same form or with subtle differences. Action may be taken at each occurrence. It is likely the issue will continue into the future, but handling the concerns are easier. Finally, in the case of example D, it may be that the level of anxiety rises even after the government intervention. The collapse of Northern Rock is such an example. In this case the intervention is seen failed to be taken quickly enough. Equally it may arise due to the alternative voices creating uncertainty and split authority. This provides the public with an unclear direction with no obvious resolution, and uncertainty led to higher levels of anxiety (Andreeva, et al., 2009).

After sometime, consumption of beef returned to a normal level after the crises. There was an interesting support for the UK approach in 2001 when the European Commissioner for Heath Consumer Safety commended UK tackling of the disease. Although the UK still had the highest rates of BSE in cattle, beef consumption was rising. The Commissioner told the European Parliament that sales had risen because: “People see that the incidence of BSE is falling. Consumers concluded that somebody is in charge, and they are doing something about it.” Other countries were criticised for years of denial which lead to shock reaction and dramatic falls in the consumption of beef by up to 50%. This illustrates both the diminishing of public anxiety with trusted behaviour, also the consequences of not acting appropriately (Andreeva, et al., 2009).

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326 commonly known as mad-cow disease

Appendix 3.2.1 Relativism (Ontological Position)

A more recent variant of the relativist position is the idea of "critical realism". It starts with the realist ontology of Bhaskhar, and then incorporates an interpretative thread (Sayer, 2000). Critical realism makes a conscious compromise between the extreme positions. It recognises social conditions (such as class/wealth) as having real consequences, whether they are observed and labelled by social scientists; but it also recognises that concepts are human constructions.

Appendix 3.2.2 Positivism

The positivist (which links with representationslism) assumed, there is a reality which exists independently/externally of the observer. Hence, the job of the scientist/researcher is to identify this pre-existing reality. This is most readily achieved through the design of experiments, which key factors are measured through objective methods, to test predetermined hypotheses (Easterby-Smith et al., 2004).

Appendix 3.2.3 Relativism (Epistemological Position)

The relativist position assumed difficulty of gaining direct access to "reality", means that multiple perspectives will normally be adopted-through triangulation of methods and surveying viewpoints/experiences of large samples of individuals. Even so, it is only a matter of probability that the views collected will provide an accurate indication of the underlying situation (Easterby-Smith et al., 2004).

Appendix 3.3.1 Five Types of Research under the Qualitative Method

(a)Exploratory: An attempt to determine whether a phenomenon exists. Central Question: Does it happen?

(b)Descriptive: Examining a phenomenon in order to define it (more) or to differentiate it from other phenomenon. Central Questions: What is it? How is it different?

(c)Predictive research: Identifying relationships that enable us to speculate about one thing by knowing about something else. Central Questions: What is it related to? What next after this?

(d)Explanatory: Examining the cause-effect relationship between two/more phenomena. Central Question: What causes it?

(e)Action: Refers to research conducted to solve a social problem. Central Question: How can research be put to use?

Source: Omerod (1996).

Appendix 3.4.1 Online Journals

Social Shaping Technology	Risk/Risk Management	Biofuels
-Science and Public Policy	-Risks Management: An International Journal	-Renewable Energy: An International Journal
-Science, Technology and Human Values	-International Journal of Risk Assessment and Management	International Journal of Renewable Energy Technology
-Social Studies of Science	-Journal of the Society for Risk Analysis -Journal of Risk: Health, Safety & Environment	-Biofuels Journal -Biotechnology for Biofuels -Journal of Biofuels, Bioproducts and Biorefining

Source: Summarised by the researcher.

Appendix 3.4.2 (a) Questionnaire for the Scottish Government Representative

Section A: General Questions

Date/Time	
Name	
Company/Department	
Designation	
Job functions	

1. How biofuels become one of the current renewable energy sources for road transport?

2. Why do you think biofuels have been opted to dominate the UK market, rather than other alternatives resources?
**Is there any political, social, economic, technological or environmental factors involved for such consideration? Please explain.*

3. Since the UK is a unitary state with a devolved system of government, what are the Scottish Government's roles and responsibilities in:
(a) biofuels deployment?
(b) biofuels development?

4. What are the mechanisms instituted in order to create a supportive environment for the oil companies in pursuing:
(a) biofuels deployment and
(b) biofuels development in Scotland?
**Any rules and regulations set? Any incentives or funding allocated to the oil companies to carry out biofuels implementation and R&D?*

5. What are the risk and uncertainty faced by the UK/Scottish Government during:
(a) biofuels deployment?
(b) biofuels development?
**Political support, funding, social acceptance, environmental, technology, institutional interest (Elliott, 2003), or environmental impacts?*

6. How does the UK/Scottish Government deal with such risk and uncertainty occurring during:
(a) biofuels deployment?
(b) biofuels development?

7. How far do you think these risk and uncertainty would affect biofuels deployment and development in Scotland or the UK as whole?
**Do you think these risk and uncertainty would jeopardise the progress and cause the failure of biofuels implementation and innovation?*

Section B: Specific Questions

8. How does the UK/Scottish Government ensure that, biofuels deployment is under control; while the next generation biofuels is going to be successfully developed?

9. How does the Scottish Government respond to the:
(a) UK RTFO (2008)
(b) EU Biofuels Directive (2003)
**Any direct involvement of the Scottish Government during the decision-making at the UK*

and the EU level?
**Or it is merely the Scottish Government follows what is instructed by the UK and the EU Government?*

10. In your opinion, which is the most important factor for biofuels implementation in the UK market? Why?
**Generally there are few driving forces such as energy security, climate change, prospering agriculture, green economy. However, we believe, there is the factor of localisation, which determines the local needs/requirements for biofuels commencement.*
**Any particular policy or evidence which signifies the importance of the factor that you have mentioned?*

11. How far do you think biofuels could be implemented?
**Is it until 2010, since the EUBD (2003) specifies the target of 5.75% by 2010?*

12. What are the consequences if the RTFO targets fail to be achieved?

13. Since biofuels are any kind of fuel made from living things or waste they produce; has the UK/Scottish Government specified which types of feedstock should be used for existing supply and future production?
**If yes, which feedstock? If no, why not?*

14. Does the UK/Scottish Government enforce the biofuels standards on bioethanol and biodiesel?
**If yes, which standard? If no, why not?*

15. Do you think Scotland will able to produce sufficient biofuels for its own market consumption? Why?
**If not, then how will Scotland fulfil the future demand?*

16. What are the implications of the RTFO execution in Scotland?
**social implications/economic implications*

17. How does the Scottish Government gain public acceptance of biofuels implementation in Scotland?

Issues of Systemic Risks
1. What do you think about the comments made by the pressure groups, that biofuels have caused pressure for:
(a) food-fuel competition?
(b) biodiversity destroyed?

2. How does the UK/Scottish Government deal with these issues in
(a) sustaining the public interest and,
(b) supporting the industries for further participation in the progression of biofuels deployment and development?

3. How does the UK/Scottish Government response to the pressure from social movements, media and environmentalists?

4. Why does the UK Government not wait until the next generation biofuels is commercially available, before executing the RTFO?

5. What do you think about the claim from environmentalist that "biofuels is a quick fix for energy demand"?

Some other quotations which could be used:

(a) Lester Brown, founder of the Washington-based Worldwatch Institute: "The competition for grain between the world's 800 million motorists, who want to maintain their mobility, and its 2 billion poorest people, who are simply trying to survive, is emerging as an epic issue." (Earth Policy Institute, 2008).

(b) Jean Ziegler, Vice-President of the UN Human Rights Council's Advisory Committee: "The effect of transforming thousands of tons of grains into biofuels is absolutely catastrophic for the hungry people. So it's a crime against humanity to convert agricultural productive soil into soil [which] will be burned into biofuels. What has to be stopped [is] the growing catastrophe of the massacre [by] hunger in the world" (Ziegler, 2007).

(c) "While Europeans maintain their lifestyle based on automobile culture, the population of Southern countries will have less and less land for food crops and will lose its food sovereignty. In other cases, energy crops will be grown in Latin America, as well as in Asian and African countries, at the expense of our natural ecosystems. The problem of climate change generated by the countries of the North cannot be solved by creating new problems in our region. We are therefore appealing to the governments and people of the European Union countries to seek solutions that do not worsen the already dramatic social and environmental situation of the peoples of Latin America, Asia and Africa" (Latin and South American Network, 2007).

(d) Bill Sutherland, Chair in Conservation Biology, Cambridge University: "We need to have the science ready before policies are made, and products are on the market. The necessary science was not done before the introduction of biofuels. In terms of the environmental consequences and societal concerns, we should have through of all these things before" (Sutherland, 2008).

Issues of Global Financial Crisis

1. How does the Scottish Government envisage the future of biofuels and evaluate the prospects?

**Since we are now in the recession.*

2. Do you think that the current economic climate would affect biofuels implementation and R&D?

**Any projects which have been put on-holdt due to investment cuts?*

3. Overall, do you think the biofuels policy has gained success in implementation? Why?**Any indicative measurement/tangible results?*

Appendix 3.4.2(b) Questionnaire for the Oil Companies Representative
Section A: General Questions

Date/Time	
Name	
Company/Department	
Designation	
Job functions	

1. What are the roles of your company in:
(a) biofuels deployment
(b) biofuels development

2. What has stimulated your company's interest to embark on the route of pursuing:
(a) biofuels supply and
(b) biofuels innovation

3. Why has your company prioritised biofuels supply and development over other types of renewable energy?
**Is there any political, social, economic, technological or environmental factors involved for such consideration? Please explain.*

4. Has the knowledge and experience of petroleum products been directly applicable to biofuels?

5. How does your company react to the government initiatives to effectuate biofuels deployment and biofuels development in the UK/Scotland?
**Policies formulated such as the RTFO (2008).*
**Requirements from the RFA on reporting system and Meta/Qualifying standards.*
**Does your company have direct/indirect involvement for decision-making at the UK and EU regulatory level?*
**Or is your company merely followin what is instructed by the EU/UK/Scottish Government?*

6. What do you think about the government's mechanisms instituted for biofuels deployment and development in the UK/Scotland?
**Adequate mechanisms to facilitate biofuels implementation and innovation?*
**Clear rules and regulations set? *Are they helpful?*

7. What are the risk and uncertainty your company face during:
(a) biofuels deployment
(b) biofuels development
**Technology, business operations, technology innovations, social acceptance advocated by Rosenbloom and Kantrow (1982), Pearson (1991) and Rosenberg (1994)*

8. How does your company deal with risk and uncertainty occur during:
(a) biofuels deployment
(b) biofuels development

9. How your company is going to ensure that biofuels deployment is under control; while the next generation biofuels is going to be successfully developed?
**Any strategy? Any tangible results? Any corporate policy which defines so?*

Section B: Specific Questions

10. How does the involvement of biofuels affect your company's current business (in oil and gas)?
**Do biofuels compete with your existing business profiles?*

11. Which factor is currently being prioritised by your company in the UK biofuels adoption? Why?
**Energy security? Climate change? Prospering agriculture? Transition to green economy? Shareholders/management decisions? Corporate social responsibility?*

12. How far do you think biofuels could be implemented?
**Is it until 2010? Since the EUBD specifies the target of 5.75% by 2010. Would it be implemented until year 2012 as being specified under the Kyoto Protocol?*

13. What consequences arise if your company fails to achieve the RTFO targets?

14. Which types of the next generation biofuels is your company currently pursuing? Why?
**the 2G-lignocellulosic biomass*
**the 3G-algae*

15. How does your company respond to the technical developments in biofuels-changes between generations in feedstock?

16. If the feedstock can be wide in range, then:
(a) How can the feedstocks' quality be controlled?
(b) How can the quality standardisation of biofuels be confirmed?
**This is due to the fact that if the quality of biofuels does not meet industry standards or being standardised, it can create problems or cause significant damage to engine components.*

17. Do you think there is an opportunity for inviting non-petroleum players (agricultural) in producing biofuels which could compete with the oil companies?

18. How does your company compete with other the oil companies in biofuels?

19. How does your company manage the supply chain of biofuels?

20. Do you think biofuels are the absolute solution for transport energy? Why?
**or perhaps it is one of the options?*

Issues of Systemic Risks

1. Do you agree that biofuels have caused pressure for:
(a) food-fuel competition
(b) biodiversity destroyed

2. What do you about think the claim from environmentalists that "biofuels is a quick fix for energy demand"? Some other examples:

(a) "The accelerated destruction of rainforests due to increasing biofuels production can already be witnessed in some developing countries. Sustainable production outside Europe is difficult to achieve and to monitor" (European Environment Agency's Scientific Advisory Body, 2008).
(b) John Beddington, the UK Chief Scientist (2008) "It is very hard to imagine how we can see a world growing enough crops to produce renewable energy and at the same time meet the enormous increase in the demand for food."
(c) Robert Zoellick World Bank President (2008) "While many are worrying about filling their gas tanks, many others around the world are struggling to fill their stomachs.
(d) Hartmut Michel, 1998 Nobel Prize winner for Chemistry (2008) "When you convert into biofuels, you add fertilizer, and then harvest the plants. There's no real energy gained in biofuels. When you burn the forest, you produce too much carbon dioxide, which you can't save in the next several hundred years."
(e) Sir David King. the UK Former Chief Scientific Officer (2008) "There is enough evidence now that the White House having introduced to favour biofuels in the US has created quite a massive diversion of food crop products into biofuels production and hence pushed up prices of food, particularly in developing countries."
(f) Louis Michel, European Development Commissioner (2008) "It is clear the use of forests for the manufacture of biofuels is dangerous. The use of arable land to produce the resources necessary for biofuels could be detrimental to agricultural production."

3. How does your company resolve these issues?
(a) food-fuel competition
(b) biodiversity destroyed

4. How does your company respond to the pressure from social movements, media and environmentalists?

Issues of Global Financial Crisis

1. How does your company envisage a biofuels future and evaluate the prospects? **Since we are now in the recession.*

2. Are there any particular government policies which have influenced your corporate strategy in pursuing biofuels?
**Any helpful policies which stimulate your company's business?*
**Any policies are forceful which might affect to your company's business?*

3. Do you think the current economic climate will affect biofuels implementation and R&D?
**Any projects which have been put on-hold?*
**Any strategy implemented to deal with this economic climate?*

4. What is important to your company in order to stand out amongst other biofuels suppliers?

Appendix 3.4.3 Interviewing Under a Field Condition

There are some important points which need to be considered when interviewing designated people. The ultimate objective is to maximise the information obtained through the limited time allocated.

(i) Before the Interview
-Courteous, being well prepared and self-confidence are important.
-The topic of the research has to be interesting in order to capture the respondent's

attention.
-“Speaking their language” (do not sound too academic/theoretical sound) is important to create coherence.
-If he/she is interested, he/she will agree to to the appointment. If he/she refuses, then the researcher has to respect his/her decision.

(ii) Contacting Respondents and Setting up the Appointment
-Many times, the researcher reviewed the respondent's information: his/her name, designation and scopes of their job in advance. If this information could not be obtained, the researcher would obtain it from his/her introducer.
-Knowing his/her position and the scope of his/her job are important. This is to ensure the questions set are appropriate to his/her job function.
-Be prepared for no second chance or returned interview. Thus, within the time available for the appointment, maximising the quality of information obtained is important.
-The researcher used email to make the initial contact with the prospective interviewees. This signified a more interpersonal touch and could receive a decision in a quick manner.
-Sending letters through post was an alternative option. This was used only if the researcher has been requested to demonstrate his identity-by providing supporting letter written by the principal supervisor.
-If the researcher has the opportunity to fix an appointment date and time, then he would:
(a) Avoid an appointment set on Monday or Tuesday. An appointment set on Friday is a good option. Psychologically, the respondent would appear to be more relaxed, since generally Saturday is not a working day.
(b) Propose that the interview would begin at 10am. This is aimed to leave at least 30 minutes to an hour before lunch time. Hence, a time set close to 12noon, or early in the morning (8am/9am) is not encouraged.
(c) Avoid interview set after lunch time. Besides, a time closes to 4:30pm/5pm (end of normal office hours) is not encouraged.
-A follow up telephone call was used to remind the respondent, a week and then again one/two days before the interview.
-Good preparation was important to understand the basic information. The interview was aimed to get answers of “why” and “how” type questions for justification and update which the secondary data could not answer.
-Thus, questions like “what”, “when”, “who”, “where” and “which” were the researcher's responsibility to comprehend beforehand.

(iii) During the Interview
-Time management, being efficient and being professional is important during this process.
-Punctuality is important.
-Time management is not only about the promptness of starting the interview, but also how well the researcher ends the interview on time as previously planned. Usually the researcher requested 1½ hours for the interview.
-If the respondent is keen to share more, the researcher would welcome the extra time, since more information could be obtained.

-A copy of questionnaire (with 15-20 questions) was given to the respondent, in order to guide the interview. Yet his/her copy would not have the *part shown.
-The *parts were set as a guide for the researcher and helped the researcher to probe further, and to maintain the momentum of the conversation.
-5 minutes were allocated to the respondent, so that he/she can read through these questions. This was to make him/her feel comfortable and helped prepare for the interview process. This was also one of the main reasons that the respondent agreed to have our conversation recorded by dictation phone.
-Every respondent had to answer questions from section A. Section A was related to the research questions.
-Since each respondent had different expertise and knowledge, each of the respondents would get different questions, which were selected from section B.
-Triangulation took place. The researcher intended to get new feedback/responses after previous interviews have been conducted. For example, opinions from the respondent A were used to gain feedbacks from the respondent B interviewed. The respondent B was free to comment on what he/she thought about comments made by respondent A.
-Besides, issues and comments that rose from the media and quotations from other significant representatives such as environmentalists/academicians/politicians were also used.
-This could enrich the information, as well as to understand the interactions between one stakeholder and another.
-Questionnaire (refer appendix 3.4.2a and 3.4.2b) demonstrates the questions which were asked during the interview.

(iv) Flexibility and Sensitivity in the Interview
-The questionnaire was set and pilot tested and could be finished within 1 to 1½ hours.
-A duration longer than 2 hours is not suitable. The respondent might show tiredness. If this happens, then the quality of the information get could be low.
-Apart from body language, the repetition of the answers, responses which do not answer the question, answers which are diverted too far away from the question, or any quick “I don’t know” answer might signal that the interview has begun to lose its momentum. Therefore, time is very important. This was also one of the reasons why the interview was set to last between 1 to 1½ hours.
-The researcher expected interruptions, incoming calls or colleagues walk in during the interview process. Therefore, the researcher has to be clear which part the conversation was interrupted. Therefore, shorthand was helpful in this respect.
-Important questions first, relating to the research questions were set first. Even though the questionnaire has been designed in advance, it should not be rigidly fixed and would turn the interview into a question and answer session.
-The questionnaire was merely a tool to guide the interview process. The conversation was built on the flow of the information sharing. The researcher was alert and flexible in asking questions to drive the continuity of the conversation.
-The researcher played a proactive role to guide the conversation, ensuring that the answers obtained could achieve the objective of the study. Sometimes, respondents elaborated more than what was required. Therefore, it is important that the researcher keep the process moving in the right direction and keep within the allocated time.

-The researcher respected non-disclosure answers. For those questions which the respondent declined to reveal, the researcher respected his/her decision.
-Gaining trust during interview is important. Subsequently, the researcher gained many classified and internal circulated publications which are not accessible to the public.

(iv) After the Interview
-The researcher sent an email to thank the respondents for their time and participation in the research project.
-For those with whom a good rapport had been built, a thank you card was also sent.
-Transcribed information was sent to the respondent to allow him/her check the information recorded by the researcher.

Appendix 3.4.4 Supporting Letter from Principal Supervisor

Appendix 3.7.1 Interviews Date

Designations of the Respondents	15/04/08 RTFO Execution	07/07/08 Systemic Risks Responded by the UK Government	15/09/08 Bankruptcy of the Lehman Brother
The Scottish Government			
Executive of Corporate Services Team			22/09/08
Executive of Renewable Policy Team	30/05/08		16/03/09
Executive of the Rural Directorate	12/06/08		
Policy Manager of Cleaner Vehicles & Alternative Fuels	17/04/08		01/07/09
Argent			
Public Relations of Argent Energy			10/08/09
BP			
Sustainability Strategy Manager			08/10/08
Executive of North Western Europe Exchange			01/03/09
Fuel Engineer			09/12/08
Shell			
Engineer of the Renewable Energy Team Executive in the Shell CO_2 Abatement Project			20/10/08 17/02/09 02/12/09
Procurement Executive			18/10/08
Quality Engineer			20/05/09
Biofuels Sustainability Compliance Officer			30/06/09

Source: Summarised by The Researcher.

Appendix 4.1.1 The Kyoto Protocol

The Kyoto Protocol, which follows the United Nations Framework Convention on Climate Change (UNFCCC), is one of the instruments for tackling climate change. It is an international agreement linked to the UNFCCC. The major feature of the Kyoto Protocol is, it sets binding targets for thirty-seven industrialised countries (including the EU) for reducing six major GHGs[327] emission. The total reduction of the developed countries are set to be at least 5% against the 1990 level over the five-year-period of 2008-2012-which also known as the first commitment period (Europe Publications Office. 4th January 2007).

327 [1]Carbon Dioxide CO_2, [2]Methane CH_4, [3]Nitrogen Oxide N_2O, [4]Sulphur Hexafluoride SF_6, [5]Hydrofluorocarbons HFCs, [6]Perfluorocarbons PFCs.

Recognise that developed countries were principally responsible for the current high levels of GHG emissions-as a result of more than 150 years of industrial activities; the Protocol placed a heavier burden on developed nations under the principle of “Common but Differentiated Responsibilities”. The Kyoto Protocol is adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. In 2008, 184 Parties of the Convention have ratified the Protocol. The major distinction between the Protocol and the Convention is, while the Convention encourages industrialised countries to stabilise GHG emissions, the Protocol commits them to do so (UNFCCC, 2008).

Under the Treaty, countries must meet their targets primarily through national measures. However, the Kyoto Protocol offered them an additional means of meeting their targets by way of three market-based mechanisms:
(a) Emissions trading-known as “the carbon market”
(b) Clean development mechanism
(c) Joint implementation
These mechanisms helped to stimulate international/national investments, and supported countries to meet their emission targets (UNFCCC, 2008).

Under the Protocol, countries’ actual emissions have to be monitored, while precise records have to be kept. The registry system tracks and records transactions by countries under the mechanisms. The UN Climate Change Secretariat, based in Bonn, Germany, keeps an international transaction log to verify transactions which are consistent with the rules of the Protocol. Meanwhile, reporting is done by countries through submitting annual emission inventories and national reports at regular intervals. A compliance system is in place to ensure that countries are meeting their commitments (UNFCCC, 2008).

The Kyoto Protocol was also designed to assist countries in adapting to the adverse effects of climate change. It facilitated the development and deployment of techniques that can help increase resilience to the impacts of climate change. The Adaptation Fund was established to finance adaptation projects and programmes in developing countries. The Fund was financed mainly with a share of proceeds from Clean Development Mechanism projects (UNFCCC, 2008). The Kyoto Protocol is generally seen as an important step towards a truly global emission reduction that will stabilise GHG emissions and provides the essential architecture for any future international agreement on climate change. By the end of the first commitment period of the Kyoto Protocol in 2012, a new international framework needs to be negotiated and ratified, to ensure that the stringent emission reductions could be continued.

Appendix 4.1.2 Energy Security and GHG Reductions Concerned by Directive on the Promotion of Biofuels (2001)

(a) Energy security

In the coming twenty to thirty years, the EU oil production is expected to decline. Whereas consumption will increase, and transport demand is continue to grow. The coming decades of increased import dependency world oil demand is expected to show strong growth, and the global distribution of known oil reserves leaves the

Middle East OPEC members as the only possible suppliers to fulfil this increased demand (DPB, 2001).

(b) GHG reductions
It is recognised the necessity of reducing global GHG emissions, particularly with the Kyoto commitments for industrialised countries like the EU. This objective poses a challenge well beyond what has been asked from the car and oil industry, as drastic reduction of emissions of conventional air pollutants, virtual elimination of lead and sulphur from automotive fuels or significant improvement of fuel efficiency (DPB, 2001).

Appendix 4.1.3 Meta and Qualifying Standards
The RTFO is built around seven sustainability principles which consist of five environmental and two social principles as shown in Table 4.1.1

Table 4.1.1 Seven Sustainability Principles

Environmental principles
1. Biomass production will not destroy or damage large above/below ground carbon stocks
2. Biomass production will not lead to the destruction or damage to high biodiversity areas
3. Biomass production does not lead to soil degradation
4. Biomass production does not lead to the contamination or depletion of water sources
5. Biomass production does not lead to air pollution
Social principles
6. Biomass production does not adversely affect workers' rights and working relationships
7. Biomass production does not adversely affect existing land rights and community relations

Source: RFA (2010b)

These seven principles have been used to define the RTFO Sustainability Meta Standard. The Meta standard is a higher standard. Biofuels suppliers are also permitted to set up their own auditing procedures to demonstrate that their feedstocks meet the RTFO Meta Standard. Any scheme that meets an adequate number of the RTFO Meta-Standard criteria (but not in full) is considered as Qualifying Standard (RFA, 2010b).

The G&S market is developing, and suppliers have been putting in procedures to track information about sustainability through their supply chains. According to the RFA (2010b), this is intended that by creating a market for G&S biofuels, and that suppliers will be able to source their feedstocks increasingly G&S for socioenvironmental protection.

Appendix 4.1.4 The Renewable Transport Fuel Certificates
The RFA awards one RTF Certificate to biofuels suppliers for every litre of biofuels supplied under the RTFO. The certificates are not physical objects, and can only be working within the RTFO system. They can be traded amongst suppliers, yet the RFA does not support or facilitate any of the commercial elements of the transaction, only the transfer of ownership of the certificates (RFA, 2010c).

Certificates may be revoked if the RFA finds that inaccurate/fraudulent information was provided in the application, reporting system, or subsequent requested evidence. These certificates are used by obligated suppliers as evidence of meeting their obligation. Once an obligation period has finished, the RFA calculates the obligation of each obligated supplier. They are then asked to either redeem certificates or buy out of their obligation (RFA, 2010c).

Appendix 4.1.5 The *Gallagher Review*

The UK Government policy on biofuels has always been aimed on making biofuels production and use, green and sustainable (G&S). However, recent research on the two systemic risks-rising food prices and biodiversity threatened; have highlighted the possible effects of other factors which are not monitored by the current mechanisms.

According to Gallagher (2008), “We cannot afford to abandon biofuels as part of a low carbon transport future. Yet, equally, we cannot continue producing biofuels which are ultimately more environmentally and socially damaging than the hydrocarbon they seek to replace.” The Gallagher review, prepared by the RFA for the UK Government is responded to these systemic risks concerned. The aim has been to examine the scale of the indirect effects of current biofuels implementation and to propose solutions.

The review concluded few points: First, there is a future for a sustainable biofuels industry. However, the feedstock production must avoid agricultural land for food production. This is because, the displacement of existing agricultural production due to biofuels demand, is accelerating land-use changes. If left unchecked, this will reduce biodiversity, and may even cause more GHG emissions rather than savings. At the EU level, targets within the EURED, EU Fuel Quality Directive (EUFQD) (refer appendix 4.1.6) should recognise the need to avoid both direct and indirect land use change, which leads to significant loss of carbon stocks (Gallagher, 2008).

Second, the introduction of biofuels should be significantly slowed, until adequate controls to address displacement effects are implemented; and are demonstrated to be effective. A slowdown will also reduce the impact of biofuels on food commodity prices, which have a detrimental effect upon the poorest people. Third, it should be possible to establish a genuinely sustainable biofuels industry, provided that robust, comprehensive and mandatory sustainability standards are developed and implemented (Gallagher, 2008).

Fourth, the review proposes 5% RTFO target to be deferred in 2013/14. The review recommends that, the RTFO should be further reviewed in 2011/12, to complement and coincide with the 2011/12 EU review of member states’ progress on biofuels targets. During the period to 2011/12, comprehensive, mandatory sustainability criteria within the EURED (2009) should be implemented for biofuels. Targets higher than 5% should only be implemented beyond 2013/14, if biofuels are shown to be demonstrably sustainable. This milestone should be applied both at the EU and the UK level. If the industry fails to deliver demonstrably sustainable biofuels by 2013/14, the level of the target could also be reduced for subsequent years

(Gallagher, 2008).

Appendix 4.1.6 The EU Fuel Quality Directive

In April 2009, the EU Fuel Quality Directive (EUFQD, 2009) was adopted to revise the EUFQD (1998-Directive 98/70/EC). It amends a number of elements of the petrol and diesel specifications, as well as introducing in Article 7a-e as new sets of requirement. Targets in the EUFQD require by 2020, a minimum reduction in GHG emissions from road transport of 6% is set. The 7a and 7b laid down the criteria for GHG reduction and biofuels sustainability; while others are specifying the obligation of reporting system.

Article 7a: GHG Emission Reductions

-Requirement on fuel suppliers to reduce the GHG intensity of energy supplied for road transport. From 1 January 2011, suppliers shall report annually, to the authority designated by the Member State on:

(a) the total volume of each type of fuel or energy supplied, indicating where purchased and its origin

(b) the life cycle GHG emissions per unit of energy from fuel and energy supplied.

-Member States shall require suppliers to reduce gradually life cycle GHG emissions per unit of energy from fuel and energy supplied at least 6%, up to 10% by 31 December 2020. This reduction shall consist of the intermediate targets: 2% by 31 December 2014 and 4% by 31 December 2017 (EUFQD, 2009).

Article7b: Sustainability Criteria for Biofuels

-Biofuels shall not be made from raw material obtained from land with high biodiversity value, namely:

(a) primary forest and other wooded land, that is forest and other wooded land of native species, where there is no clearly visible indication of human activity and the ecological processes are not significantly disturbed;

(b) areas designated by law/authority for nature protection purposes; or

(c) for the protection of rare, threatened, endangered ecosystems/species recognised by international agreements or included in lists drawn up by intergovernmental organisations or the International Union for the Conservation of Nature, subject to their recognition in accordance (EUFQD, 2009).

Appendix 4.2.1 Delegation Power between the UK and the Scottish Government

Scottish devolution is the delegation of power from the UK Parliament and the UK Government to the Scottish Parliament and the Scottish Government. The Scottish Parliament has been given the power to make laws on certain issues such agriculture, forestry, environment and transport. These issues are known as devolved matters.

Some of the issues concerning Scotland, that have a UK or international impact are dealt with by the UK Parliament. These issues are known as reserved matters like foreign affairs, international relations, relations with territories outside the UK/the European Communities (and their institutions) other international organisations, regulation of international trade, international development assistance and cooperation. Thus the UK Parliament can also make laws that will apply to Scotland on any subject, but it does not normally legislate on devolved matters and without the consent of the Scottish Parliament (The Scottish Parliament, 2008).

Appendix 4.2.2 The Scottish Government Renewable Action Plan 2009

The Renewable Action Plan (RAP, 2009), is the latest policy which demonstrates the SG's visions/missions embarking on the green economy pursuance, as well as its achievements in various RE development projects. Even though the previous EU/UK/Scottish climate change policies have laid down the initial visions and aims for green economy pursuance, yet most of these policies were constructed during 2000-2007. They are outdated and could not reflect the actual scenario of economic challenges since the 2008 world financial crisis occurred. Besides, these policies highlighted the political awareness at the urgency of combating climate change by reducing GHG/CO_2 emission, yet did not outlines how to put such political messages into actions.

The RAP (2009) sets the world most ambitious target. By 2020, Scotland is aim for 42% of carbon reduction from the country. Subsequently, the RAP is set for a decade of unprecedented activities in this sphere, to ensure related activities are developed/established, so that this target could be achieved on time. The RAP demonstrates the SG's new thoughts, planning, new decisions made, latest information about RE development and strategies to such achievements. Taking into the consideration of the recent 2008 world financial crisis, it is crystallised by taking in most of the previously constructed EU/UK/Scottish policies, working under the realism of economic pressures, then turns them into visions/missions and objectives for measurable actions.

The policy mainly covers the decarbonisation of electricity, heat supply and low carbon vehicles through RE generation. The primary electricity, heat and transport milestones for 2020 are set, as 50% of electricity, 11% of heat and 10% of national transport fuels would sources from RE (RAP, 2009).

There are seven objectives of the SG in pursuing RE generation (RAP, 2009):
(a) to maximise the economic, social and environmental potential of Scotland's renewables resource, across different technologies;
(b) to establish Scotland as one of the leaders in the UK and wihitn the EU;
(c) to reduce the time for renewables to become cost-effective;
(d) to ensure maximum returns for Scotland's domestic economy, in terms of jobs creation, company wealth and IP generated, inward investment secured and tonnes of carbon saved;
(e) to meet the targets for energy from renewables, and for emissions reductions, to 2020 and beyond;
(f) to maximise the confidence of developers, investors, and the workforce that these are unambiguous, long-term commitments, the SG-led, but with durable cross-party political backing;
(g) to ensure an advantageous integration between the activities of the SG, the UK and the EU Government.

Appendix 4.2.3 Regional Selective Assistance

The RSA is the main national investment grant scheme of financial assistance to

businesses in designated areas of Scotland in the Assisted Areas. It is aimed for wealth creation and to safeguard employment. There are two criteria for eligibility under the RSA Scheme: First the size of a business (small, medium or large businesses) and location of a business-which categorised under:
-Tier 1(businesses located at highlands and islands),
-Tier 2 (country sides) and
-Tier 3 (which include cities and urban areas).
These areas are designated for regional aid under European Community Law (The Scottish Executive, 2008).

Appendix 4.2.4 The UK Biotechnology and Biological Sciences Research Council

The BBSRC is one of the seven the UK research councils. It obtains its funds from the Department for Business, Innovation and Skills. The BBSRC supports research in life sciences. It annually invests around £420 million in a wide range of research that contributes to the quality of life for the UK citizens and supports a number of important industrial stakeholders including the agriculture, food, chemical, healthcare, pharmaceutical and biosciences (BBSRC, 2009).

Appendix 4.2.5 Sustainable Bioenergy Centre

The SBC's research activities encompass different stages of biofuels production, from widening the range of materials that can be the starting point for biofuels, to improving the crops by making them grow more efficiently to changing plant cell walls. Besides, the SBC will also analyse the economic and environmental life cycle of potential sources of bioenergy. This centre represents a £27M investment that increases UK bioenergy research capacity. It brings together six research hubs of academic and industrial partners, based at: University of Cambridge, University of Dundee, University of York, Rothamsted Research and two at the University of Nottingham. This is aimed to create a network with expertise and specialist resources that span the bioenergy, from growing biomass to fermentation for biofuels (SBC, 2009).

Appendix 4.2.6 Six Research Hubs

There are six research hubs which are conducting six different types of research programmes:
(1) Perennial Bioenergy Crops Programme
-Optimising biomass yield and composition for sustainable biofuels. The programme aims to improve yields of fast growing trees and grasses, to make more of the plants' carbon available for conversion into biofuels, without increasing inputs such as fertilizers. Leads by the Rothamsted Research, with associated programme members: Institute of Biological, Environmental and Rural Sciences (IBERS), Imperial College London and University of Cambridge.

(2) Cell Wall Sugars Programme
-Developing strategies to improve plants and enzymes for increased sugar release from biomass. The programme aims to better understand how sugars are locked into plant cell walls, by selecting the right plants and the right enzymes to release the maximum amount of sugars for conversion to biofuels. Leads by the University of

Cambridge with associated programme members: Newcastle University, Shell and Novozymes.

(3) Lignocellulosic Conversion to Bioethanol Programme
-Using agricultural and wood-industry wastes, to create material to produce fuels. It will also work on microbes which could efficiently turn the material into fuel. Leads by University of Nottingham with associated programme members: University of Bath, University of Surrey, BP, Bioethanol Ltd, Briggs of Burton, British Sugar, Coors Brewers, DSM, Ethanol Technology, HGCA, Pursuit Dynamics, SABMiller and Scottish Whisky Research Institute.

(4) The Second Generation Sustainable, Bacterial Biofuels Programme
-Optimising production of the more effective 2G biofuel (biobutanol) from non-food biomass. Biobutanol is better than bioethanol but currently available microbes used in biobutanol production processes are inefficient, produce unwanted by-products and cannot use plant cell walls directly as a feed material. The programme aims to generate and test new bacterial strains to overcome this. Leads by University of Nottingham with associated programme members: Newcastle University and TMO Renewables.

(5) Cell Wall Lignin Programme
-Improving barley straw for lignin production and transferring the new knowledge to other crops. Lignin is a polymer in plants that makes it difficult to access sugars for bioenergy production. The programme aims to alter lignin properties in barley to make it easier to produce biofuels without reducing the quality of the crop. Leads by University of Dundee with associated programme members: University of York, Scottish Crop Research Institute (SCRI), the Rural and Environment Research and Analysis Directorate (RERAD).

(6) Marine Wood Borer Enzyme Discovery Programme
-Creating new enzymes for the conversion of non-food plant biomass into biofuels from marine wood borers. Wood and straw contain polysaccharides that if converted to simple sugars could be fermented into biofuels. At the moment the market does not have suitable enzymes to break down these woody materials. However, marine wood borers consume huge amounts of woody material and their guts have all the enzymes needed to break it down. Leads by University of York with associated programme members: University of Portsmouth and Syngenta Biomass Traits Group.
Source: The University of Dundee, 2009.

Appendix 4.2.7 Examples of the Next Generation Biofuels News from the Scottish Government Website
(a) Biomass Action Plan for Scotland (2007)
-The 2G biofuels can be derived from a number of sources including non-food biomass, dedicated energy crops and biomass resources currently viewed as residue such as straw and forestry. Some of the advantages include the potential for significant farm-to-wheel reductions in GHG emissions, and reduced land use requirements as most biomass can be used as a feedstock. The 2G biofuels should also avoid some of the technical problems associated with the 1G biofuels such as

degradation and material incompatibility. In the EU Biomass Action Plan, the Commission commits to substantially increasing its support for the development of the 2G biofuels through its research budgets.

(b) Bioenergy (2008b)
-The 2G biofuels projects are likely to be very large scale and developments in Scotland would result in a highly competitive market for the available resource. Using biomass for energy offers a number of benefits as if properly planned it can be carbon neutral and sustainable. We need to recognise, however, that there are competitor industries for biomass supply and that it needs to be able to demonstrate its economic as well as its environmental benefits. A focus on local supply initiatives will therefore be important.

(c) Cleaner Vehicles and Alternative Fuels (2008c)
-With the emergence of viable technologies, to convert commonly available mixed or segregated waste streams into bioethanol, biobutanol, biodiesel and biogas. The use of waste materials in this context tends to confer improved life cycle carbon benefits on the final fuel. The R&D into the 2G biofuels is being carried out across the globe. Currently, while not commercially available, such fuel has been produced from hydro-cellulosic material (biodegradable/organic waste e.g. stalks and plant matter from forestry or agriculture). Some of the recent R&D into the use of marine algae has also taken place.

(d) Draft Framework for the Development and Deployment of Renewables in Scotland (2008d)
-The greatest potential for the NGB is lignocellulosic wastes.
-Increase research into the 2G and the 3G biofuels along with marine biofuels. Again, huge potential, but all the sustainability criteria have to be met before incentivising their use.

Appendix 5.1.1 BP and its Energy Businesses
(a) BP Exploration and Production
There are two clusters of Exploration and Production business: First, the upstream: includes oil/natural gas exploration, field development and production. Second, the midstream: involves the management of crude oil/natural gas pipelines, processing, export terminals and LNG processing facilities. Three major pipelines are within the midstream activities: the [1]Trans Alaska Pipeline System; the [2]Forties Pipeline System and the [3]Central Area Transmission System pipeline both in the UK sector of the North Sea.

Besides there are three major LNG plants: the 1Atlantic LNG plant in Trinidad, 2Indonesia (BP and Sanga-Sanga Production Sharing Agreement, supplies natural gas to the Bontang LNG plant) and in 3Australia (through its share of LNG from the North West Shelf natural gas development). Currently, BP has exploration and production interests in twenty-five countries, include the US, the UK, Russia, Norway, Canada, South America, Africa, the Middle East and Asia (BP. 2010a).

(b) BP Refining and Marketing

BP's Refining and Marketing business is responsible for supplying, trading, refining, marketing and transportation of crude oil and petroleum products to wholesale and retail customers. The products reached over one hundred countries, operating in Europe, North America, Australasia, parts of South East Asia, China, Africa, Central and South America. In oil refining, BP owns (wholly/in part) twenty-one refineries, which: five in the USA, seven in Europe and five in other parts of the world. Besides, through JV with TNK, BP has accessed to four refineries in Russia.

There are three business areas in marketing: retail, lubricants and business to business marketing reaching worldwide markets. These products include gasoline, gasoil, marine/aviation fuels, heating fuels, LPG, lubricants and bitumen. BP's aromatics and acetyls businesses recently joined this business segment, with proprietary technology and benefits from strong positions in the growing Asian markets. Acetyls products are used as chemical intermediates in the production of derivative products of consumer goods. In addition, aromatics chemicals are raw materials for aromatics chemical purified terephthalic acid (PTA), a chemical intermediate for polyester fibres, films, containers and polyethylene terephthalate (PET) bottles (BP, 2010b).

(c) BP Alternative Energy

The Alternative Energy covers a wide range of renewable and alternative energy technologies, from large scale commercial businesses in solar, wind power to carbon capture and advanced biofuels. The aim of BP Alternative Energy is to provide secure, sustainable energy that is valued by customers and governments worldwide. With investment running at USD1.5billion a year, the alternative energy business demonstrates the scale of BP’s commitment to the clean technology sector. BP Alternative Energy has substantial businesses in solar photovoltaic, wind and gas-fired power, and is developing projects in advanced biofuels, carbon capture & storage, and concentrated solar thermal power. BP Biofuels is blending and distributing today’s bioethanol and biodiesel, investing in research to explore advanced biofuels that will emit less carbon and use non-food crops (BP, 2010c).

Appendix 5.1.2 The US Renewable Fuel Standard program 2005

The US Environmental Protection Agency (EPA) is proposing to modify the national Renewable Fuel Standard (RFS) program. The RFS-1 was established under the Energy Policy Act 2005 (EPAct) which amended the Clean Air Act. The US Congress gave EPA the responsibility to coordinate with the US Department of Energy, the US Department of Agriculture, and other stakeholders to design and implement this new program (US Environmental Protection Agency, 2009).

On 8 August 2005, President Bush signed the 2005 Energy Policy Act into law. The comprehensive energy legislation includes a nationwide RFS-1 that will double the use of bioethanol and biodiesel by 2012. RFS-1 that started at 4 billion gallons in 2006 will increase to 7.5 billion gallons in 2012. It also provides beginning in 2013, a minimum of 250 million gallons a year of cellulosic derived ethanol (besides the conventional bioethanol) to be included (Renewable Fuels Association, 2005).

Under the Renewable Fuel Standard Program (RFS-2), US Environmental Protection Agency is finalising changes to the Renewable Fuel Standard Program (RFS-1), as required by the Energy Independence and Security Act of 2007, to ensure that transportation fuel sold in the US contains a minimum volume of renewable fuel. The new requirements increase the volume of biofuels required to be blended into transportation fuel to 36 billion gallons by 2022. The rule was developed in collaboration with refiners, renewable fuel producers, and many other stakeholders (United States Environmental Protection Agency, 2010).

Appendix 5.1.3 Carbon Neutrality

Activities along biofuels value chain such as seeding, fertilising, irrigating, growing, harvesting, transporting, manufacturing and distributing; which each requires energy inputs. Every unit of the energy input is correlates with carbon emissions. Thus, lower energy input would lower the emission. Besides, land use could change the GHG/CO2 emissions. High biodiversity areas should be protected, and not to be turned into biofuels plantations. These areas are playing their role as green lungs, and potentially have the capability for carbon sink.

Appendix 5.1.4 European committee for Standardisation (CEN)

CEN is a major provider of European Standards and technical specifications. It is the only recognised European organisation according to Directive 98/34/EC for planning, drafting and adoption of European Standards in all areas of economic activity (except electrotechnology and telecommunication). These standards have a unique status since they also are national standards in each of its 30 Member countries. With one common standard in all countries, thus every conflicting national standard is withdrawn. Consequently, a product can reach a far wider market with much lower development and testing costs. European Standards help building a European Internal Market for goods and services trading (European Committee of Standardisation, 2009).

Appendix 5.1.5 Low Carbon Vehicle Partnership

The LowCVP is a not-for-profit action and advisory group that is established in 2003 to take a lead in accelerating the shift to low carbon vehicles and fuels in the UK. It is a partnership of over 300 organisations from automotive and fuel industries, the environmental sector, government, academia, road user groups and other organisations with a stake in the low carbon vehicles and fuels agenda (Low Carbon Vehicle Partnership, 2009).

Appendix 5.2 BP's Ten Next Generation Biofuels Development Projects

(a) BP and the Energy and Resources Institute (TERI) India, 2006

BP is funding a USD9.4 million on Jatropha project, implemented by TERI (refer appendix 5.2.1) in the Indian State of Andhar Pradesh, to demonstrate the feasibility of producing biodiesel from jatropha Curcasan (refer appendix 5.2.2).

New explained: “Because Jatropha is drought resistant and can grow on marginal land, it offers the possibility of an economically and environmentally sustainable.” The project is expected to take 10 years, will cultivate 8,000 hectares of jatropha on land which currently designated as wasteland. Besides, the project could produce approximately 9 million litres of biodiesel per annum (BP, 2 February 2006).

This is a mutually benefiting project. BP is acting as the project funder, while TERI is the project executor. TERI is responsible for the day-to-day management/execution of the project: from farming to biodiesel production. Thus, BP could tap into India for jatropha cultivation, while TERI has the profit making opportunity-to produce biodiesel at commercial scale. Furthermore, the project is benefiting the local economies, as it provides employment opportunity and captures foreign direct investment from BP.

(b) BP and DuPont, 2006
BP has been working with DuPont[328] and they formed the JV company called Butamax Advance Biofuels since 2003. This company aims to explore new approaches at biofuels development that would perform better than bioethanol. The first product which is going to be produced is biobutanol. Construction has begun on a biobutanol demonstration plant in Hull, UK, by using a wide variety of processed cereal feedstocks[329]. The pilot plant will produce 20,000 litres of biobutanol per year, which can be blended into petrol at various concentrations. This plant is expected to begin production in 2009-2010 (BP, 2009h). According to the Fuel Engineer from the interview, biobutanol is a solution for the weaknesses found in the existing bioethanol. Biobutanol has higher energy content than bioethanol, provides better engine performance and could enhance the fuel efficiency.

(c) Energy Biosciences Institute, 2007
Energy Biosciences Institute (EBI) (refer appendix 5.2.3) is a BP owned in-house R&D organisation, dedicated to the new field of energy bioscience. It focuses on the development of the NGB and various applications of biology to the energy sector. Established in February 2007, EBI represents collaboration between three American universities[330] that conducting research activities, while BP supports the institute financially with a ten year USD500 million grant (EBI, 2008).

The formation of EBI is at the early stage running by these three universities, and BP will venture on the learning curve to acquire know-how in strengthening its institutional knowledge on bioscience/biotechnology. Reflected from the interview: “We call this as big science. We are working with world's leading researchers to explore how bioscience can be used to increase energy production, and to reduce the impacts of energy consumption on the environment,” said the Executive of NWEEP.

Justifying the selection of these three American universities, Jim Breson, BP's Project Manager who led the setting up of the EBI explained: “One of the key reason for selecting Berkeley and its partners was because, these institutions have excellent track records of delivering “big science” research that is: large, complex

[328] DuPont is a science company. Founded in 1982 and operating in more than 70 countries. DuPont offers a range of innovative products and services for markets including agriculture and nutritious (BP, 20 June 2006).
[329] corn, wheat, sugar beet, sorghum, cassava and sugar cane (BP, 2006b).
[330] The University of California Berkeley, The Lawrence Berkeley National Laboratory and The University of Illinois.

developments aimed at making scientific breakthroughs that can subsequently be deployed in the real world as engineering applications" (Knott, 2007). Therefore the expertises, experiences, track records and reputations for these three American universities have convinced BP to fund USD500 million in order to get the institute established.

The EBI will concentrate at the 2G biofuels in the early stage. According to the interview: "We have identified areas where we need the breakthroughs for making the next generation biofuels technically and economically viable. EBI is researching broader aspects of energy bioscience as its staffing levels build up. However, its first task is into lignocellulosis[331] biofuels," said the Sustainability Strategy Manager.

The EBI establishment received a positive response from the California Governor. BP's decision on three universities (in California), not only enhances the reputation of these universities and the state, but also benefiting economically and socially for the local community. First, corporate tax and relevant taxes (income tax, value added tax on equipments, property tax) could generate income for the state's treasury. Next, the local employment opportunities will be opened to magnetise local/foreign high skilled and knowledge workers (scientists/researchers) working for the EBI. Third, further economic gains through research contributions like patents creations, innovative solutions, transferring research knowledge to the public, setting up research infrastructure; all of these would build a strong foundation for future bioenergy business proliferation, human capital development, attracting further FDI from the related industry and nurturing the local community/society towards energy bioscience literacy.

Through local media, the California Governor responded: "The private sector has recognised the stature of the University of California, and our state's commitment in transforming to a clean energy future. This is a complement to our new low carbon fuel standard, which more than triple alternative fuel demands in California by 2020. With the research facilities like the EBI, California will continue to be the leader in the Cleantech industry" (Office of the Governor, 2 January 2007).

(d) BP and Mendel Biotechnology, 2007

In June 2007, BP entered a collaboration agreement with Mendel Biotechnology[332] of California, to develop high yielding energy grasses[333], as part of its investigation into alternative biofuels sources. BP is funding a five-year research programme conducted by Mendel. Mendel has experience in establish breeding programmes of perennial grass for variety improvements. As such, Mendel will accelerate this project by establishing breeding stations in the Midwest/South East of USA, as well as by promoting further cooperation with agriculture research groups in Germany

[331] Lignocellulosic refers to plant biomass composed of cellulose, hemicellulose, and lignin. These complex structure of carbohydrate polymers can be extracted through fermentation to produce bioethanol.

[332] Mendel Biotechnology core expertise is about plant gene and pathway function which enable accelerated improvement in plant varieties, through new genetic and chemical solutions to meet agricultural and energy production needs (Mendel, 2008).

[333] miscanthus, elephant grass, switchgrass, sorghum are candidates for lignocellulosic biofuels feedstocks.

and China (BP, 2007a).

This is because, energy grasses growing requires suitable climate, soil types, natural irrigation (amount of rainfalls) and skilled labour for seeding, growing and harvesting. The breading stations set in different locations could imply the empirical testing, to determine geographical suitability for types of energy grass cultivation. According to the Fuel Engineer from the interview: "Different types of energy grasses could provide many alternatives for the 2G biofuels production. Not only they are non-food which can evidence no food-fuel competition, but also the large quantity of perennial energy grasses (sustain for five to seven years) could ensure a consistent supply for biofuels production".

Through collaboration with BP Biofuels Business Unit in May 2007, Mendel has begun to create proprietary varieties of energy grasses for the 2G biofuels (Mendel, 2009). Generally, is Mendel's expertise that has attracted BP's interests to have the project invested. Since Mendel's core expertise is at plant gene, its institutional knowledge of gene function enables the identification of natural/synthetic chemicals which can alter plant performance in useful ways. Mendel has discovered the functions of genetic that control many important aspects of plant growth, metabolism, stress responses and productivity[334]. By modifying these key genes, the project is aimed to obtain significant improvements in plant productivity towards higher yield with minimal resources (water, nutrient) consumptions (Biopact, 2007).

(e) BP, British Sugar and DuPont Producing Vivergo Fuels, 2007

On 26 June 2007, together with British Sugar, BP and DuPont have started building a USD400 million world scale bioethanol plant at Hull, UK; with a capacity to produce 420 million litres of bioethanol annually from locally grown wheat. The production is expected to begin in 2010. The feedstock for the plant initially will be wheat, consuming some 25% of the UK's average annual wheat surplus. Although initial production will be bioethanol, the partners will look at the feasibility of converting it to biobutanol once the required technology is available (BP, 2007a; BP, 2007b; BP, 2009i). The bioethanol plant, BP and British Sugar would each hold 45%, with DuPont owning the remaining 10%. Explained by the Sustainability Strategy Manager from the interview, this collaboration allows the companies to focus jointly on developing biofuels by making use of BP's fuels expertise and access to major fuel markets; British Sugar's experience in the agricultural value chain links to feedstock supply; together with DuPont's biotechnology and biomanufacturing capabilities.

(f) BP and D1 Oils, 2007

On 29 June 2007, BP and D1 Oils[335] have established a 50/50 JV partnership, named as D1-BP Fuel Crops Limited, to accelerate the planting of Jatropha Curcas. The JV

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[334] Mendel uses advanced transgenic breeding techniques to improve yields, drought and freezing tolerance, disease resistance and the efficient use of nutrients in biomass crops (Mendel, 2009).

[335] D1 Oils pioneering the development of Jatropha curcas, provides commercial technology and services to the Jatropha sector, includes breeding, selection of Jatropha seeds/seedlings, the development of planting practices, husbandry methods, harvesting, processing of Jatropha oil (as source of biodiesel) and meal for animal feed like hog (D1 Oil PLC, 2009a).

is aim to produce biodiesel for commercial scale. According to Elliot Mannis, CEO of D1 Oils: “Our strategy is to produce inedible oil sustainably from jatropha for low-cost production of biodiesel.” Further responded from Iain Conn, CEO of BP’s Refining and Marketing Business: “This joint venture is a further milestone in our strategy to contribute to global energy supplies in ways that are sustainable and progressive” (BP, 29 June 2007).

BP will invest USD90 million from a total JV investment of USD160 million over the next five years, and D1 Oils will contribute to the JV with its 172,000 hectares of existing plantations in India, Southern Africa and South East Asia. The investment will be made through directly managed plantations on owned/leased land; as well as through contract farming and seed purchase agreements, which will provide significant employment for local communities. It is anticipated, some one million hectares will be planted over the next four years, with an estimated 300,000 hectares per year thereafter (BP, 29 June 2007). Once plantations are established, the JV is expected to become the world's largest commercial producer of jatropha feedstock, producing up to 2.2 billion litres of jatropha oil per year (BP, 2007a).

Supported by the interview from the Sustainability Strategy Manager: “Much of the jatropha oil produced from the plantations will be used to meet local biodiesel requirements and for export to Europe. The domestic European feedstock from rapeseed and waste oil is unlikely to be sufficient to meet anticipated demand (of round 11.2 million tonne equivalent per year from 2010). Therefore jatropha could provide a consistent supply of biodiesel”. According to New: “Once all the planned plantations are established, the joint venture is expected to become the world’s largest commercial producer of jatropha feedstock” (BP, 29 June 2007). Further explained by New: “As jatropha can be grown on land of lesser agricultural value with lower irrigation, it also exhibits a better CO2 balance, as less fertiliser is required to raise it. This hardy crop can make a significant impact on employment in local communities of developing countries” (BP, 29 June 2007).

Talking about the latest stage of the BP-D1 jatropha project, the Sustainability Strategy Manager explained: “Currently jatropha is still under testing. We are waiting to see the yields and see how it performs with different amount of irrigation and difference types of land. The plant will grow anywhere. You plant in a middle of park it will grow. But how many gallons of oil you get out from jatropha growing in desert or in proper land, is something we are investigating now.” The manager's view is supported further by BP's publication. Currently, D1 Oils’ progress in identifying the most productive varieties of jatropha, means the project will access to seeds which can substantially increase jatropha oil production per hectare (BP, 29 June 2007).

(g) BP, Arizona State University and Science Foundation Arizona, 2007

In November 2007, BP has established a research partnership with Arizona State University (ASU) and Science Foundation Arizona (SFAz) (refer appendix 5.2.4) to develop biodiesel. The research effort focuses on using a specially optimised photosynthetic bacterium to produce biodiesel. The SFAz agreed that a group of ASU researchers will receive USD2.2 million over two years, while BP will collaborate with the ASU team and contribute funds equal to SFAz's grant. As such, total of

UDS4.4 million has been injected into this project (Flinn Foundation, 2 November 2007).

The representative from the ASU and SFAz welcomed this research partnership. William Harris, the President and CEO of SFAz responded: "The proposal from ASU was backed due to the calibre of scientists leading the project and the great untapped potential of microorganism driven biofuels production. This collaborative gives Arizona the opportunity to lead in solar technology[336] and reap enormous benefits: environmental impacts, wealth generation resulting from commercialised technologies and economic implications for entire regions" (Caspermeyer, 2007).

The use of photosynthetic bacteria in the production of biofuels eliminates the need for costly and complex processing. In addition, the large-scale microbial cultivation, using only solar energy and a controlled production facility, can be set up on arid land. ASU President, Michael Crow commented: "Because the bacteria are dependent upon CO_2 for growth, a more environmentally friendly and potentially carbon neutral energy source is feasible." The bacterial biodiesel production allows the technology to be placed adjacent to power generating stations and the utilisation of flue gas as a carbon source (Caspermeyer, 2007). This helps towards total carbon reduction as whole.

The utilisation of bacterium to produce biodiesel has opened a potential source for production, which can support the biofuels manufacturing mix, to provide a consistent future supply. The good criterion of this technology-it is a direct conversion from bacterium into biodiesel without going through the conventional process of transesterification. Besides, this could reduce the production cost. Furthermore, the direct conversion by using solar power could eliminate the energy inputs, which results lower CO_2 emission. Since the technology utilise solar power and CO_2 (emission from power stations) this method, if further developed could be a carbon sink instrument, and classified as the 4G biofuels.

(h) BP and Tropical BioEnergia S.A, 2008
Currently, sugarcane is the most efficient source of bioethanol available. Brazilian sugarcane with its bioethanol production has achieved 80% reduction of life cycle GHG emission. With more than three decades of production experiences, Brazil has become the giant in the bioethanol business (BP, 2008c). Brazilian flex-fuel vehicle sales are now at 94% of total market sales (Biofuels Digest, 11 September 2009), so the drivers can switch fuels whenever the prices change.

In 2008, BP is JV with Tropical BioEnergia (refer appendix 5.2.5), to help BP meets its goal of providing more quantity, secure, greener and affordable biofuels (BP, 2008c). BP has a 50% stake in Tropical (with USD59.8million financial injection). The first plant in Edéia, Goias State is scheduled to commence operation in the second half of 2008. It is anticipated to reach full capacity of 435 million litres per year by mid 2010. Furthermore, the JV also intends to build a second bioethanol refinery, investing a total of approximately USD1 billion in the two refineries (BP,

[336] using solar to optimise photosynthetic bacterium in producing biodiesel.

2009d). From the interview, explained by the Executive of NWEEP: “Once both refineries in full operation, they will be able to supply large demand in Brazil and can also export to US, Europe and Asia.”

“Given today’s global interest in reducing dependency on hydrocarbon, Tropical Bioenergia gives BP a position in the sugarcane ethanol industry in Brazil,” said Paulo Pinho, Head of BP's Biofuels Venture, Brazil. “Brazil is producing around 22 billion litres of sugarcane ethanol per year, according to its industry organisation UNICA (refer appendix 5.2.6)”. With two harvests per year, sugarcane is plentiful in Brazil, and studies show that there is enough arable land available to support production of biofuels without having an impact on land for food crops, or sensitive areas such as Amazon rainforests. In fact the farm areas are distance 600 miles from the edge of the rainforest (Kolmar, 2009). Meanwhile, New responded: “This investment represents a significant step in delivering BP’s strategy for biofuels which centres around sustainable feedstocks, do not impact on food supplies and investing in research work to develop the technologies required to produce the next generation biofuels” (BP, 2009d). Besides, the sugarcane not only could produce the 1G bioethanol, but also its bagasse[337] can be a source for the 2G bioethanol feedstock.

Supported by the interview and secondary data: “The sugar has been going down of its pricing for the last two years for the massive volume available. It is something that we receive of good investment. Obviously, biofuels will revolve into lignocellulosic (the 2G) within five to ten years from now. In the mean time, we have our investment in Brazil,” said the Sustainability Strategy Manager. According to Jorge Maeda, CEO of Maeda Group. “We are demonstrating how Maeda’s agriculture expertise, attendant network of relationships, and knowledge of the region’s soils, climate and rural labour conditions combined with Santelisa Vale’s sugarcane expertise can provide sustainable renewable and reliable solutions for fuel”. “BP’s logistical, technological and fuel supply chain experience will enable a significant enhancement of our strategic plans,” said Anselmo Lopes Rodrigues, CEO of Santelisa Vale (BP, 2009d). From this JV, Tropical will focus on sugarcane production, manufacturing and marketing of bioethanol, including the associated agricultural assets and cogeneration power plants[338] (BP, 2009d). BP will provide the international market access, the blending facilities to take Brazilian bioethanol into the global market.

(i) BP and Verenium Corporation, 2009

The scientific evidence shows, cellulosic bioethanol from biomass (the 2G bioethanol) will deliver clean, sustainable fuel that have the potential to reduce GHG emissions up to 90% (BP, 2009j). On 18 February 2009, BP and Verenium Corporation[339] announced the formation of a 50-50 JV, under the name Vercipia

[337] Bagasse is fibre remaining after the extraction of the sugar-bearing juice from sugarcane. It may be used as fuel in the sugarcane mill or as a source of cellulose for animal feeds (poultry). Paper is produced from bagasse in several Latin American countries, in the Middle East, and in all sugar-producing countries that are deficient in forest resources. It is the essential ingredient for the production of pressed building board, acoustic tile, and other construction materials (Encyclopedia Britannica, 2008).

[338] using bagasse to generate power for the plant production.

[339] Verenium Corporation possesses the capabilities in pre-treatment, enzyme development,

Biofuels, to develop and commercialise cellulosic bioethanol from non-food feedstocks. Vercipia will act as the commercial entity for the cellulosic bioethanol development. Together, BP and Verenium have agreed to commit USD112.5 million each, in funding and building up assets to the USD225 million invested at Vercipia.

This JV is intended to progress the design and engineering required for the development-one of the US's first commercial scale cellulosic bioethanol facilities, located in Florida. Responded by Carlos A Riva, President and CEO Verenium: "The creation of this joint venture company brings together innovative and experienced developers, designers, engineers, operators and managers capable of realising the potential of this technology. This is a convergence of industrial biotechnology and energy production processes that will allow us to deliver cleaner, more sustainable biofuels" (BP, 2009j).

Meanwhile, Sue Ellerbusch, President of BP Biofuels North America responded: "Our relationship with Verenium demonstrates our commitment to making cellulosic bioethanol a reality in the US market in the near term. BP and Verenium together have the technological know-how, engineering capability and market expertise to demonstrate that we can deliver better, more sustainable biofuels, more quickly." (BP, 29 July 2009). Vercipia will focus on securing financing for the first commercial-scale cellulosic bioethanol facility in Florida, and expects to break ground on that site in 2010. Production from this plant is expected to begin in 2012, will have the capacity to produce 140 million litres of bioethanol per year.

Since announcing the formation of Vercipia, it has been selected with due diligence on the US Department of Energy (DOE) Loan Guarantee for the project. This shows the US Government is supporting the 2G biofuels development. The project will signify the US Government's vision towards home-grown biofuels (for the sake of national energy security), fulfil American's Renewable Fuel mandates (refer appendix 5.1.2) for GHGs reduction, building nation's domestic infrastructure (for biofuels supply/distribution) and create the green jobs within biofuels industry. With the government support, Vercipia intends to develop a second site in the Gulf Coast region to scale up the 2G bioethanol production capacity (BP, 2009j; BP 29 July 2009).

(j) BP and Martek Biosciences, 2009

On 11 August 2009, BP and Martek Biosciences Corporation[340] announced the signing of a Joint Development Agreement (JDA) to work on the production of microbial oils for biofuels applications. The partnership combines a broad technology platform and operational capabilities to advance the development of a technology for the conversion of sugars into biodiesel. Under the terms of the multi-year agreement, Martek and BP will work together to establish a large scale, cost

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fermentation, engineering, project development and commercialisation its proprietary technology for the production of cellulosic ethanol from a wide array of feedstock, including sugarcane bagasse, dedicated energy crops, agricultural waste and wood products (Verenium Corporation, 2009).

[340] Martek Biosciences Corporation is founded in 1985 with its expertise at fermentation technology and R&D of products derived from microalgae (Martek Biosciences Corporation, 2009).

effective microbial biodiesel production through fermentation (BP, 11 August 2009).

Both Martek's and BP's representatives welcomed this JDA. “BP’s global leadership and commitment to alternative energy solutions complements Martek’s own commitment to responsible and sustainable products and production,” said Steve Dubin, Martek CEO. Meanwhile New responded: “As an alternative to conventional vegetable oils, we believe sugar to biodiesel (refer appendix 5.2.7) technology has the potential to deliver economic, sustainable and scalable biodiesel supplies” (BP, 11 August 2009).

The JDA crystallised the combination of Martek's leading know-how in microbial lipid production, with BP's expertise in biofuels markets, applications and commercialisation. Besides, BP agreed to contribute up to USD10 million to this initial phase of the collaboration which leverages Martek’s expertise. Martek will perform the biotechnology R&D, whilst BP will contribute to biofuels value chain know-how. All intellectual property (IP) owned prior to the execution of the JDA will be retained by each respective company, and all IP developed during the JDA will be owned by BP, with an exclusive licence to Martek for application and commercialisation in nutrition, cosmetic and pharmaceutical applications[341] (BP, 11 August 2009).

Appendix 5.2.1 The Energy and Resources Institute (TERI)
Established in 1974, TERI launched its own research activities based in New Delhi. The strength of the Institute lies-not only in articulating intellectual challenges straddling a number of disciplines, but also in mounting research, training and demonstration projects leading to the development of specific problem-based technologies benefiting to the society at large (TERI, 2008).

There are twenty-four Indian Government's institutions which support various projects undertaken at TERI. In biofuels project alone, there are nine institutions involved. All of these nine institutions welcomed the investment from BP in the jatropha project (TERI, 2008).

Appendix 5.2.2 Jatropha
Jatropha is a non-food medicine, which conventionally being used for piles, snakebite and dropsy. It is a drought-resistant perennial, which is growing well in marginal/poor soil[342]. It is easy to be established. It grows quick and produces seeds for 50 years. It produces an oil content of 37%-40%[343], which mostly extracted from the nut seeds after two-to-five year grow. The oil could be combusted as fuel without being refined. It burns with clear smoke-free flame, and being tested as fuel for diesel engine. The by-products are press cake (an organic fertilizer) and insecticide. Jatropha grows wild in many areas of India and even thrives on infertile soil/rugged in nature. It can survive with minimum water (irrigation)/nutrient (fertiliser) inputs

[341] Biodiesel can be used in other products, apart from transport fuel.
[342] Fallow, marginal and waste land, or land which unsuitable for arable crops. Therefore jatropha would not compete with farmland or high biodiversity value areas such as rainforest (D1 Oil PLC, 2009b).
[343] higher yield than soy 20% or rape 20% (BP, 29 June 2007).

and easy to propagate (Centre for Jatropha Promotion, 2008).

Appendix 5.2.3 Energy Biosciences Institute (EBI)

EBI is a R&D organisation that harnesses advanced knowledge in biology, physical sciences, engineering, environmental and social sciences to devise viable solutions to global energy challenges, and to reduce the impact of fossil fuels to global warming. It is the world's first research institution solely dedicated to the new field of energy bioscience. EBI is focusing on the development of the NGB, but will also look into various applications of biology to the energy sector. EBI hosts approximately twenty-five research teams, housed at the University of California Berkeley campus and the University of Illinois; while the Lawrence Berkeley National Laboratory will carry out supporting research (EBI, 2008).

Apart from the NGB research, the EBI is responsible for wider energy bioscience avenues including improved oil recovery, carbon conversion and carbon sequestration. Over the next two years, the EBI team will ramp up to around 150 people, alongside with 50 BP staff; specialists in refining and fuels processing (Knott, 2007).

Appendix 5.2.4 Arizona State University (ASU) and Science Foundation Arizona (SFAz)

The Biodesign Institute at ASU is focused on innovations that improve health care; provide renewable sources of energy and bioremediation; outpace the global threat of infectious disease; and enhance national security. Using a team approach that converges the biosciences with nano-scale engineering and advanced computing, the goal is to find solutions to complex global challenges and accelerate these discoveries to market (ASU Biodesign Institute, 2008). SFAz is a non-profit organisation, delivering and managing research (scientific, engineering and medical research programs). Its innovation grants encourage collaboration between industry, government and the academic sector to leverage financial resources and human capital skills that yield measurable returns from the research outcomes (Science Foundation Arizona, 2007).

Appendix 5.2.5 Tropical BioEnergia

Tropical Bioenergia S.A is one of the country's agricultural experts which is a JV company originally-established by Santelisa Vale 25% and Maeda Group 25%. The Maeda Group is one of the largest cotton producers in the world with 80 years in the industry, while Santelisa Vale is the second largest sugarcane crusher in Brazil and the first in energy cogeneration from bagasse. Santelisa Vale with over 70 years of history operates five ethanol refineries, has expertise along the entire value chain of ethanol/sugar production (BP, 24 April 2008).

Appendix 5.2.6 The Brazilian Sugarcane Industry Association (UNICA)

UNICA is the largest organisation in Brazil representing sugar, ethanol and bioelectricity producers. Created in 1997, following a consolidation process involving regional organisations in the State of São Paulo after the government deregulation of the sugar and ethanol sectors. UNICA members answer for more than 50% of all ethanol produced in Brazil and 60% of overall sugar production, covers areas such as the environment, technology, energy, international trade, corporate social responsibility, legislation, economics and communications. In late 2007, UNICA launched its first international office in Washington D.C., followed by the opening of its European office in Brussels, with a third international office in Asia in 2008. UNICA's expanding foreign presence is an integral part of its strategy to provide consumers, government officials, NGOs, the business community and the news media with up-to-date, detailed information on vital social, economic and environmental contributions of Brazil's sugar, ethanol and bioelectricity sectors (UNICA, 2009).

Appendix 5.2.7 Sugar to Biodiesel

The sugar to biodiesel pathway uses biological science to convert sugars derived from biomass into lipids using fermentation microorganisms. The lipids are then converted into fuel molecules through chemical/thermocatalytic processes. Biodiesel produced from sustainable feedstocks via the fermentation of sugars will offer the potential to deliver GHGs reduction of up to 80-90% when compared to traditional fossil fuel. Other advantages of this sugar to biodiesel pathway over conventional biodiesel made from vegetable oils include:

(a) Access to a wide variety of biomass feedstocks such as sugar cane, sugar cane waste (bagasse), energy grass and woodchips, which can be produced at scale and in high yield.

(b) Use of sustainable, non-food, plant biomass as its feedstock.

(c) Ability to tailor the product for a variety of diesel and future jet-fuel needs.

(d) Reduced exposure to vegetable oil price.

Source: BP. 11 August 2009.

Appendix 5.3.1 Green and Sustainable (G&S) Criteria

Definitions of G&S criteria encompass three aspects:

(a) Technical criteria: must comply with the technical quality standards of biofuels EN142140-15376 for seamless distribution infrastructure and engine adaptation;

(b) Ecology criteria: by taking into account of the GHGs emission, water footprint, energy inputs, land use/changes, local biodiversity/ecosystems and global impact as whole from the international trading of biofuels (import and export activities involved from the producing nations to the importing countries);

(c) Social criteria: biofuels must not compete with food or impair food security, must provide non-discriminative working conditions (no force labour, no child labour) and does not manipulate the local communities through resources exploitation, farm land/preserved high value areas (jungle/forest) conversion to biofuels plantation, but must conduct responsible agricultural practices which will safeguard social, economic interests and environmental concerns

Source: Bioenergy and Energy Planning Research Group, October 2009.

Appendix 5.3.2 Four Biofuels Roundtables

(a) Roundtable for Sustainable Biofuels (RSB)

RSB is an international initiative coordinated by the Energy Centre at the Swiss Federal Institute of Technology in Lausanne. It brings farmers, companies, NGOs, experts, governments, and inter-governmental agencies concerned with ensuring the sustainability of biofuels production and processing.

The RSB has developed a third party certification system for biofuels sustainability standards, which consists of environmental, social and economic principles/criteria. Participation in the RSB is open to any organisation working in a field relevant to biofuels sustainability (EPFL, 2008).

On 12 November 2009, a first exploratory multi-stakeholder meeting was held at the Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland. The RSB has released Version One of its international standard for better biofuel production and processing. The vesion one includes the twelve[344] principles and criteria (P&C), associated guidance documents, detailed compliance indicators, and the glossary of terms. In 2010 the RSB Standard will be pilot tested in biofuels supply chains throughout the world to identify areas in need for further refinement (EPFL Energy Centre, 2009).

(b) Roundtable on Sustainable Palm Oil (RSPO)
RSPO formed in 2004 with the objective of promoting the growth and use of sustainable oil palm products through global standards and engagement of stakeholders. BP is one of the ordinary members[345] of RSPO.

The RSPO is located in Zurich, Switzerland, secretariat in Kuala Lumpur with a satellite office in Jakarta. It is a not-for-profit association, unites stakeholders from eight sectors[346] of the palm oil industry. This multi-stakeholders representation is mirrored in the governance structure of RSPO, lives out the philosophy of the roundtable, by giving equal rights to each stakeholder group to bring group specific agendas to the roundtable, facilitating traditionally adversarial stakeholders and business competitors to work together towards a common objective and making decisions by consensus (RSPO, 2008a)

The RSPO Principles and Criteria (P&C) were adopted in November 2005 for an initial pilot implementation period of two years and reviewed at the end of 2007 (RSPO, 2008b). This 2007 document defines eight principles with indicators and guidance for each criterion[347]. Indicators are specific pieces of objective evidence

[344] Twelve issues principles in the Version One: (a) legality, (b) consultation, planning and monitoring, (c) GHG emissions, (d) human and labour rights, (e) rural and social development, (f) food security (g) conservation (h) soil (i) water (j) air (k) economic efficiency, technology and continuous improvements, (l) land rights
Source: Roundtable on Sustainable Biofuels. 12 November 2009.
[345] There are two types of memberships offered from the RSPO. First Ordinary members are any organisations that have direct involvement in the palm oil supply chain, or associated NGOs. These members have voting rights at the General Assembly and are able to publicly state they are members of the RSPO. Second Affiliate members are individuals or organisations with an indirect involvement or interest in the palm oil supply chain, do not have voting rights and do not have the right to claim they are members of the RSPO. Up to 16 February 2010, there are 382 of ordinary members and 100 of affiliate members. BP and Shell are the ordinary member.
Source: RSPO. 2010.
[346] The eight sectors are: oil palm producers, palm oil processors, traders, consumer goods manufacturers, retailers, banks and investors, environmental or nature conservation NGOs and social/developmental NGOs.
[347] There are eight principles for sustainable palm oil production. (a) Commitment to transparency: requires oil palm growers/millers to provide adequate information on environmental, social and legal issues. The management documents for public access is established, allows disclosure of information

that must be in place to demonstrate or verify that the criterion is being met. Guidance consists of useful information to help the grower/miller and auditor understand what the criterion means in practice, including in some cases specific guidance for national interpretation of the criterion and for application by all related stakeholders.

(c) Roundtable on Responsible Soy (RTRS)
RTRS, founded in Switzerland 2006, while the Executive Secretariat is based in Buenos Aires, Argentina. It is a combination among a group of producers, NGOs and companies gathered (international multi-stakeholders. The RTRS's objective is to promote the use and growth of sustainable soy production, through the commitment of the stakeholders (farmers, producers, suppliers) of the soy value chain and through a global standard for sustainable production (RTRS, 2008).

On 28 May 2009 the version for the field tests of "Principle and Criterion" (P&C)[348] for Responsible Soy Production was approved. This represents the beginning of the application of a global standard supported by main actors of the industry, producers and organisations[349] of the civil society of the whole world, with back up of the European markets.

(d) Better Sugarcane Initiative (BSI)
BSI is a global multi-stakeholder non-profit initiative with twenty-seven members[350]

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to internal members as well as external stakeholder interested on the progress and latest information. (b) Compliance with applicable laws and regulations: mandatory require producers to comply all local, national and ratified international laws/regulations on biofuels production and supply. Rights on land use has been emphasised which will avoid diminishing of the legal rights/customary rights of local communities. (c) Commitment to long term economic and financial viability: in order to achieve long term economic and prospering the palm oil industry as whole. (d) Use of appropriate best practices by growers and millers: to emphasis on the operating procedures, documentations, to maintain soil fertility for optimal/sustained yield, avoid soil erosion/degradation, maintain the quality of surface and groundwater and avoid agrochemical pollutions. (e) Environmental responsibility and conservation of natural resources and biodiversity: to mitigate the negative impacts by good agricultural practices, consistent implementation with effective monitoring, integrated pest management, wastes management. (f) Responsible consideration of employees and of individuals and communities growers and mills affected: through occupational health and safety plan execution and consistent communication. (g) Responsible development of new plantings: from proper site planning and non-high biodiversity areas by using soil surveys and topographic screening. (h)Commitment to continuous improvement in key areas of activity: for future practices and updates
Source: RSPO. October 2007.

[348] There are five principles with twenty seven criteria for implementation on responsible soy. (a) Legal compliance and good business practice. (b) Responsible labour conditions. (c) Responsible community relations. (d) Environmental responsibility. (f) Good agricultural practice.
Source: RTRS. 2010a

[349] Up to 15 February 2010, there are 114 members in the RTRS. Both BP and Shell are the members of RTRS. There are four categories of memberships: (a) Producers 20 members, (b) Industry, finance and trade 59 members, (c) Civil society 15 members, (d) Observers 20 members. Only individuals/organisations such as regulatory authorities, governmental agencies, consulting and auditing firms, academia and donor organisations, which do not belong to one of the three constituencies, may request membership as Observing Members.
(a), (b), and (c) are participating members, while (d) is observing member.
Source: RTRS. 2010b.

[350] Up to date, there are twenty seven members in BSI: Bacardi, BP, Coca-Cola, Ethical Sugar, International Finance Corporation, Solidaridad, Tate and Lyle, Unica, Cargill, Cadbury, ED&F Man,

dedicated to reduce the environmental and social impacts of sugarcane production. Its aim is to development a code of conduct[351] to certify sustainable practices (BSI, 2008). The emphasis on sustainability is now a commonplace in the sugarcane sector where energy use, production efficiency, elimination of waste and the effect on global climate change are all being closely monitored. Therefore, BSI recognises the wide range issues connected with sugarcane cultivation and focus on a few significant social and environmental concerns such as: soil productivity, water use, agrochemical use, effluent management, biodiversity maintenance and equitable labour.

Appendix 5.3.3 Biomass, the 2G Bioethanol Feedstock

The 1G bioethanol is currently derived mainly from sugars and starches in crops such as cereals and sugarcane. However, other substances that occur in plants in greater proportions than sugars and starches-notably cellulose, hemicellulose and lignin, could possibly be converted into bioethanol.

Generally, there are three sources of biomass: First, it could be obtained from the agricultural residues (leaves, stem, stalks, roots, corn stover, wheat straw, bagasse) of even the entire plant after fruits have been harvested. This is aim to maximise the reuse and recycle of the whole plant, rather than just the fruit grains as currently under practice. Second, some species of tall, fast-growing energy grasses: such as miscanthus and switchgrass offer the potential to be converted into lignocellulosic bioethanol, could exhibit higher ethanol yields per hectare than the current food derived feedstocks. Third, the woods/forest residues such as leaves, branches, un-merchantable wood left in the forest after the cleaning, thinning or final felling of forest (BP, 2007a).

Appendix 5.3.4 The GM Crops in the US

The enhanced yields available from the current generation of GM crops such as corn and soybeans help the US farmers to meet the growing feedstock demand for biofuels while still producing sufficient quantities of food and animal feed. In fact, GM crops have helped the US farmers to increase yields by 30% over the past 10 years. This relationship between GM crops and biofuels has blossomed in the US, which claim as the largest single market for both GM crops and biofuels. In particular, it is GM corn accounting for 73% of all the corn planted in the US in 2007 and being the main feedstock for US ethanol production (Evans, 2008). Furthermore, the US is also the largest producer of Sorghum. In 2006, bioethanol production for domestic used consumed nearly 26% of the nation's sorghum crop. The R&D of sorghum is underway to improve higher efficiency in bioethanol production

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Pangea, Shell, British Sugar, EID Parry, Vicini, CAEL, Kenana Sugar, Terrain Natural Resouce Management, Reef Catchment, Syngenta, Central Romana, WWF, Consorcio Azucarero Central, Neltec Denmark, Greenergy and Cevasa.
Source: BSI. 2010.

[351] There are five principles under the code of conduct for members of the BSI: (a) Obey the law (b) Respect human rights and labour standards (c) Manage input, production and processing efficiencies to enhance sustainability (d) Commit to continuous improvement in key areas of their business (e) Actively manage biodiversity and ecosystem services.
Source: BSI. 2009.

(Dinneen, 2007).

Appendix 5.3.5 Mechanisms of Biofuels Carbon Savings

(a) GHG/CO2 Saving from Tailpipe

When biofuels blends are used at 5%, this could allow direct 10-15% of GHG/CO2 reduction from the tailpipe (Sekab Biofuels and Chemicals, 2009).

(b) Carbon Neutrality

Looking at biofuels carbon neutrality in a bigger picture, carbon in the form of a molecule of CO_2 is absorbed from the atmosphere by a plant during photosynthesis. The vegetations then converted into biofuels, burned in the vehicle's engine, and then carbon released back into the atmosphere as one molecule of CO2 -a cycle that is theoretically neutral in terms of carbon equation (BP, 2007a; Knott 2007).

Appendix 5.3.6 Energy Grasses

The 2G biofuels is a general classification of using biomass. There are three types of biomass as, discussed at appendix 5.3.3. This section, we will look at energy grasses. According to BP's Cellulosic Biofuels Fact Sheet (2009p), there are five benefits of adopting energy grasses:

(a) They can be stored in bales until they are needed, which offers great flexibility for biofuels production.

(b) They contain large amounts of the sugar held in their cell walls, can produce between 1000-2000 gallons of biofuels per acre, compared with around 400-500 gallons per acre for corn. This means more fuel produced from each tonne of feedstock, and each acre of land, in comparison with any conventional the 1G biofuels feedstocks.

(c) Energy grasses can be grown on lower quality agricultural land that is not suited to growing food crops.

(d) Due to the grow-ability of energy grasses, it is possible to grow these feedstocks needed in close proximity to the facility where biofuels will be produced. This means that the agricultural footprints of the feedstocks are smaller as the transportation of the feedstocks can be minimised. This improves both the cost and the environmental impact of the required logistics and transport aspects of biofuels production.

(e) They do not require fertilisers. Hence the emissions of Sulphur, Nitrite and CO_2 can be eliminated.

Through partnership formed in February 2009, BP and Verenium are developing bioethanol via energy grasses. Due to the benefits of energy grasses provided, and applicability of the technology, BP-Verenium JV has commenced the construction of the US’s first commercial scale cellulosic bioethanol facilities, located in Florida.

Appendix 5.3.7 BP JV with Tropical BioEnergia: Good Example for Brazilian Sugarcane

In 2008, BP has announced its investment in Tropical BioEnergia, a bioethanol producer in Brazil, JV established by Santelisa Vale-the second largest sugarcane crusher in Brazil, and Maeda Group-one of the largest cotton producers in the world (BP, 2008d). The Brazilian sugarcane is the most effective carbon saving crop (offers the potential to deliver GHGs reduction of up to 80-90% when compared to traditional fossil fuel), and cost efficiently produced. New said, “It is part of our approach of integrating sugarcane and lignocellulosic biofuels with advanced technologies to produce products with a wide range of uses." (BP, 11 August 2009).

(a) G&S Criteria of Brazilian Sugarcane

Brazilian Sugarcane is a sustainable feedstock, producing the most efficient biofuels available today. Brazilian bioethanol production using standard practices typically achieves a reduction of up to 90% in life cycle GHG emissions (BP, 2008d). Apart from sugar extractions, the whole sugarcane plant has been fully exploited towards maximisation of the bioethanol production. Some of the literatures and BP publications rename sugarcane as "Energy Cane", where this new term reintroduction is to identify sugarcane's multiple functions as source for food, drugs, medicine as well as biofuels.

There are five benefits of Brazilian sugarcane which characterised as the most sustainable feedstock for current implementation (BP, 2008d). These have been implemented effectively in Brazil for more than three decades, which shows the significant practicality.

(i) Sugarcane is planted once every five to six years and requires less energy consumption than annual crops, such as grains.

(ii) Bagasse, first by-product of sugarcane can be burned to produce energy in the form of power and steam. This can be used to fuel the fermentation process, with excess power being exported to the grid. The refinery is expected to export 30MW of power to the grid annually from 2010 onwards.

Further explained by the Sustainability Strategy Manager from interview: "Our joint venture with Tropical BioEnergia, we plan to export excess renewable energy generated from bagasse back into the state grid and turning vinasse, into fertiliser."

(iii) Second harvest by-product, vinasse, can be used to restore nutrients to the soil, reducing requirements for energy-intensive nitrogen and potassium fertilizers.

(iv) Third fertilizer by-product, filter cake, a phosphorous-rich product that can be used as an organic fertilizer to promote sugarcane growth, further reducing the need for hydrocarbon-based fertilizers.

(v) Fourth by-product, molasses[352], can be used as an animal feed for cattle and poultry.

(b) Land Use for Sugarcane Planting

The sugarcane feedstock is planted on land that has previously been planted with other non-food crops, such as cotton, or under-utilised pastures. The land is more than a thousand kilometres from the Amazon and has no impact on deforestation on Amazon. Besides, sugarcane is a semi-perennial root crop and well managed sugar cane cultivation can help to restore soil carbon in areas which have been degraded (BP, 2008d).

This is further support from the interview: "We are focusing on using land that is been under-utilised and carry out EIA (Environmental Impact Assessments)[353] to

[352] Good quality molasses can be used to make medicine (as it is rich in calcium, magnesium, potassium and iron), baking ingredient, food additive, base materials for fermentation into rum and tobacco. Low quality molasses can be used for minor component of mortar for brickwork, fishing ground bait and animal feed (BP, 2008d).

[353] guided by UNICA-SugarCane Industry Association of Brazil , local government

help us avoid negative impacts related to land use changes. We take the rights of local people (their rights for unpolluted environment) when we enter into commercial arrangements such as land acquisitions. We also seek guidance from the World Bank and the Roundtable for Sustainable Biofuels," commented the Sustainability Strategy Manager.

(c) Sugarcane has Small Impacts on Soil Erosion
Due to sugarcane is a semi-perennial crop replanted every five to six years, sugarcane has a relatively small impact on soil erosion. Each year, some bagasse is left on the soil. It leaves a thick carbon-rich layer which can improve the ability of the soil to hold water and increases the amount of organic matter in reducing erosion. The BP-Tropical BioEnergia JV has been cultivating a nursery of native sugarcane tree, which will be planted to further minimise soil erosion, protect waterways and promote biodiversity. The aim is to plant 60,000 trees, in key locations around the plantation over the next 5 years (BP, 2008d).

(d) Water Utilisation in Sugarcane for Minimal Pollutions
Brazilian sugarcane fields require practically no irrigation because rainfall is abundant and reliable in the main South Central production region where the project is based. During the short dry season, when some irrigation is required, the water comes mainly from water-rich vinasse, recycled water, or from small rain-fed ponds scattered throughout the plantation (BP, 2008d).

Naturally, sugarcane does not require excessive irrigation as they are growing in tropical zones where conditions are warm and wet. In Brazil, rain provides almost all the water the crops require. Therefore enough amount of precipitation would not put stress on the water consumption. In a responsible way of managing water footprint, the Sustainability Strategy Manager from the interview explained: "We have carried out EIA (Environmental Impact Assessments) for our operations in Brazil and plan our water use accordingly. The adequate rainfall helps a lot for our sugarcane plantation in Brazil."

(e) Employees and Health and Safety Executive (HSE) in Sugarcane Plantation
As the project employs around 1,000 people, many of whom work in the fields has been protected under the HSE. The joint venture has established a code of conduct, containing principles that guide the operations of the business. Each employee receives a copy of the code and induction training to learn about it. The code is also used in the procurement of goods and services. The safety practices and standards include induction safety training, a range of safety briefings and campaigns, including fire fighting, road safety have been implemented, with personal protection equipment is issued to all employees working in the plantation, as well as in the production plant (BP, 2008d).

Appendix 5.4.1 Advantages of the Sugar-to-Diesel Pathway
(a) Access to a wide variety of biomass feedstocks such as sugarcane, bagasse, energy grasses, woodchips or other cellulosic material.
(b) Ability to tailor the product for a variety of diesel and bioethanol needs. Hence this is an adding value to the lignocellulosic feedstocks, which not only can be used

to produce bioethanol, but also biodiesel. This helps to diversify biodiesel feedstocks, which will not entirely depend on the oil-seeds (grains or jatropha), but also could be sourced from potent sugar.
(c) Reduced the exposure to fluctuations in the global price of vegetable oils, which will consistently maintaining the production cost and gaining further profits from the product.
(d) Biodiesel produced from these specified sustainable feedstocks via the fermentation of sugars will offer the potential to deliver GHG reductions up to 80-90% when compared to conventional diesel (BP, 2009r).

Appendix 6.1.1 Shell's Expertises
(a) upstream business-Shell continuously in searching for fresh/recovers oil and natural gas all over the world (Shell, 2010a).
(b) downstream business-Shell downstream businesses include refines, supplies, trades and ships crude oil worldwide; manufactures and markets a range of products such as lubricants, and produces petrochemicals for industrial customers (Shell, 2010a).
(c) technology development-Shell manages its projects for both fossil energy (FE) and renewable energy (RE) development, driving the research and innovation to create technological solutions for both FE and RE. The FE outcomes are Shell V Power, Shell Diesel Extra, Liquified Petroleum Gas. The ongoing RE are hydrogen (H_2), solar, biofuels and wind (Shell, 2010a).

Appendix 6.2 Shell's Seven Next Generation Biofuels Development Projects
(a) Shell JV with Iogen Corporation, 2002; extended in 2008
Shell-Iogen[354] JV, is focused in developing bioethanol derived from wheat straw. The project takes place in Canada, as Canada is the world sixth biggest wheat producers in 2009 (FAO, 2009) and wheat straw is abundant. Taking wheat straw as the primary feedstock, Shell could secure this vast quantity of biomass available for the 2G bioethanol production. Besides, bioethanol made from wheat straw provides a significant reduction of CO_2, which comparatively better than the corn bioethanol.

This is supported by the Engineer of the Renewable Energy Team from the interview: "This collaboration is the first Shell's investment for the lignocellulosic biofuels. The fuel made from wheat straw, capable to reduce CO_2 up to 90% compared to gasoline we are using now."

In 2008, Shell and Iogen announced an extended alliance, each holding 50% equity to accelerate the development of cellulosic ethanol since after 2002 (Shell, 15 July 2008). Thus, this evidence, as early in 2002, Shell has demonstrated its ambition in fast track the market entry strategy through the 2G bioethanol R&D with Iogen. Hence, Shell's early the 2G research could lead to an earlier production, which enables Shell in gaining a bigger market share.

Since the partnership began in 2002; the JV has resulted the first demonstration plant

354 Iogen Corporation is established in the 1970s, with its expertise to produce cellulosic ethanol, manufacturer and marketer of enzyme for application in production processes (Iogen Corporation, 2009).

opened in Ottawa in 2004. This plant currently is a pilot plant, which is testing for cellulosic bioethanol production. Once the plant could demonstrate the production capacity required, it then could be upgraded for a full-scale commercial production. This is supported by Sweeney, Shell Executive Vice President of Future Fuels and CO_2 “We have come a long way on this particular technology pathway for sustainable biofuels and we will be working closer to meet the technical and commercial challenges facing larger scale production” (Shell, 15 July 2008).

(b) Shell JV with Choren Industries GmbH, 2005, Extended in 2008
Shell-Choren[355] JV, is working to develop a new fuel from wood residue, the Biomass to Liquids (BTL). The partnership began in 2005, and the first demonstration plant in Freiberg has started in producing BTL fuel since 2008 (Shell, 2008). According to Routs: “Shell is committed to a secure, affordable and sustainable energy supply in the future. With our investment in the BTL, Shell-Choren are driving innovation in low-carbon fuels for sustainable mobility” (Shell, 17 April 2008).

The opening of the Freiberg plant marked the completion of the world’s first production plant to convert biomass into synthetic diesel fuel. The German Chancellor Angela Merkel visited the plant on 17 April 2008, which attracted high attentions from the local media. The plant was built by Choren, capable to produce 18 million litres of fuel per year (Shell, 17 April 2008).

The BTL[356] gasification technology is a patent owned by Choren. Through the partnership, Shell is utilising Choren's expertise to produce the 2G biodiesel. The BTL technology is significantly different from the transesterification process, and effective to produce large quantity of biodiesel. Since BTL's feedstocks are taken from biomass[357], the usage of these feedstocks does not pressure the food chain. Besides, one litre of BTL will need less than 1/3 of the land required to produce one litre of rapeseed biodiesel. BTL promises to reduce 90% of CO_2, compared to conventional diesel; and it is compatible with standard diesel engines and existing diesel supplying infrastructure.

Previously, biomass has been widely recommended for heat and power generations at specific buildings, such as offices or residential apartments. For example, the Queen Margaret University in Edinburgh is using biomass for heat generation at some of its building (QMU, 2008). Yet, BTL of Shell-Choren is a world first commercial scale technology successfully being developed, where two automobile manufacturers Volkswagen and Daimler recognise it as SunFuel. The uniqueness of BTL is, it does

355 Choren is a gasification technology company for solid biomass and oil based residue feedstock. The gasification technology is the patented Carbo-V process that made the production of tar-free synthetic combustion gas possible. The technology provides a breakthrough for the conversion of biomass to energy. The process now can be used to generate power for transport (Choren Industries GmbH., 2008).
356 The Fischer-Tropsch (FT) synthesis is used to convert the synthesis gas into an automotive fuel. During this process, the reactive parts of the synthesis gas (CO and H_2) interact with a catalyst to form hydrocarbons (HC). This method was developed in Germany in 1920s, and it has been materialised through Choren's technology in R&D and commercial scale production (Choren, 2009a).
357 forest residues, agriculture residues and waste wood

not need to be blend with the fossil diesel, because it has a high cetane number and carrying better ignition performance than conventional diesel. Besides, it has no aromatics or sulphur could significantly reduce pollutants from exhaust emissions (Choren, 2009b).

(c) Shell JV with HR BioPetroleum (HRBP) Forming Cellana, 2007
Shell and HRBP[358] has formed a JV company named Cellana. The company is constructing a pilot demonstration facility on the Kona coast of Hawaii, to grow marine microalgae and produce vegetable oil (biodiesel). This project is approved by the Hawaii Department of Agriculture on the selected Kona coast (location) for facility construction (Shell, 11 December 2007). The local government approved the site for pilot facility in Hawaii which is leased from the Natural Energy Laboratory of Hawaii Authority.

The facility is growing only non-genetic modified (natural) marine microalgae species in open air ponds. Protection of the local environment and marine ecosystem has been central to facility design, to avoid the microalgae spread that will threaten the coastline and marine habitats. Besides, an academic research programme is supporting the project in screening natural microalgae species to determine which has the highest yield of oil. The research programme includes scientists from the Universities of Hawaii, Southern Mississippi and Dalhousie, in Nova Scotia, Canada (Shell, 11 December 2007).

The technical characteristics of microalgae are promising, as it grows rapidly, high-yield in oil and can be cultivated in hydro surroundings (ponds of seawater). Some microalgae species grow so fast that they double their size three/four times in one day. Besides, microalgae produces at least fifteen times more oil per hectare than rape, soy or palm. This means they can be harvested frequently- an advantage over crops which are only harvestable a few times a year (Shell, 11 December 2007). Furthermore, microalgae has higher CO_2 saving. According to the Executive of CO_2 Abatement Project Team from the interview: "Microalgae is a sustainable feedstock for biodiesel production with a very small CO_2 footprint, nearly zero carbon if we can manage it well."

The executive further explained about the concept of zero carbon. The microalgae does not require fertiliser. The nutrients can be obtained from the mineral-rich seawater. The production plant will be build near to the cultivation site, which minimise the feedstock transportation. If a well plan landscape has been adopted, the microalgae slime can be transported through pipes connected to the factory directly. Besides, manpower is currently utilised for the harvesting which minimise the use of machineries on field (refer appendix 6.2.1). Only water circulation and production would use energy, and these two activities are seeking a lower carbon footprint[359].

358HRBP is a Hawaii-based RE technology company focused on utilising the marine micromicroalgae to produce biofuels feedstocks. HRBP proprietary processing technology, called ALDUO technology, leverages the photosynthetic power and rapid growth characteristics of micromicroalgae to convert sunlight, CO_2, and nutrients into vegetable oil (biodiesel) (HR BioPetroleum, 2009).
359 Utilise altitude differences to pump in fresh seawater and flow out treated pond seawater through

However, carbon emission from processing would be trade off from the growing, harvesting and transporting which has nearly zero carbon emission. For long-term, microalgae cultivation facilities also have the potential to absorb industrial waste or capture CO_2 directly from industrial facilities, which acts as carbon sink instrument.

This JV involves Shell providing funding and fuel marketing expertises, while the local partner HRBP providing the products, technological know-how, experiences and local access (in Hawaii) for microalgae plantation. About the business prospect, Routs commented: "Currently, a pilot facility is under way in Hawaii to grow marine microalgae and produce biodiesel. If the first step goes well, we will build a demonstration-scale commercial facility. But we need to keep our feet on the ground. It will take five to ten years before we may be able to produce this biodiesel in commercial quantities" (Shell, 29 October 2008).

(d) Shell Collaborates with Virent Energy Systems, 2008
Shell and Virent[360] announced a joint R&D to convert sugars directly into fuel (biogasoline) rather than bioethanol. The collaboration could herald new biofuels that can be used at high blend rates in standard gasoline engines. Virent's technology, patented as "BioForming" uses catalysts to convert sugars into hydrocarbon.

Shell and Virent have collaborated for a year on the research. According to Randy Cortright, Virent CTO, Cofounder and Executive Vice President said: "Virent has proven that sugars can be converted into the same hydrocarbon mixtures of today's gasoline blends. Our products match petroleum gasoline in functionality and performance. Our results to date fully justify accelerating commercialisation of this technology" (Shell, 26 March 2008). Through the partnership, Shell is utilising Virent's expertise to open another path for biofuels production, which is significantly different from the fermentation process, yet effective to produce biogasoline in large quantity. This technology formed as one of the production mix, supporting the supply chain towards sustainable biofuels production.

After two years of collaboration, Shell and Virent announced the start of production. According to Luis Scoffone, Vice President of Alternative Energies at Shell: "Moving from lab-scale to a demonstration production plant is an important milestone for biogasoline.'' On the other hand, Lee Edwards the CEO of Virent responded: "The successful start-up, which was on-time and within budget, demonstrates the potential for scalable, commercial manufacturing of high quality renewable fuels." This renewable fuel that provides high performance, reliability, and lower emissions are now closer to reality as a viable alternative for transportation fuel. The demonstration plant is located at Virent's facilities in Madison, Wisconsin USA. It has the capacity to produce up to 38,000 litres per year, which will be used

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potential energy mechanism. Adopting RE source (tidal, wave or wind since it is located at coast line) to power the production.

360 Virent is founded in 2002, with its ground-breaking discoveries in 2006 by expanding the BioForming™ technology to convert plant sugars into hydrocarbon molecules. These hydrocarbon mixtures can be used directly or blended seamlessly to make conventional liquid fuels. Biogasoline is the first liquid fuel Virent produced through using this technology, followed by diesel and jet fuel (Virent Energy System Inc, 2008).

for engine and fleet testing (Shell, 23 March 2010).

(e) Shell Funds Six Universities through the NGB Research Agreements, 2008
On 17 September 2008, Shell announced six[361] new research agreements with experts in six academic institutions across the world (Shell, 17 September 2008). The R&D programmes are funded by Shell, aimed to investigate new feedstocks and new biofuels production processes, with a focus on improving efficiencies and lowering production costs. The research agreements will last between two and five years. The team now is working at four Shell-owned research centres: Thornton in Chester, UK; Westhollow in Houston, US; Amsterdam, Netherlands; and Bangalore, India, with the equipped research facilities for the work to be undertaken (Shell, 17 September 2008).

Utilising academic research towards commercial application can bring at least four benefits for both parties. First, Shell can tap different fresh ideas grounded from the theoretical based (which is the core strength for most of the academic institutions), turning them into commercial applications. Second, these academic institutions can participate in the process to materialise, test run and apply their knowledge/expertise in producing commercially oriented results. Along the process of **commercial oriented research,** these institutions are pursuing throughout the learning curve, gradually building up their institutional knowledge from the projects conducted. If the outcomes are successfully developed (which attracts Shell's interest), this could commence another level of business cooperation, for both parties in profits seeking through the findings/patents commercialisation.

Third, the research collaboration with Shell can enhance the good name of these academic institutions. The brand name of Shell would embellish the reputation of these institutions. Most of the academic institutions would be honoured to have such reputable company to be their projects funder. This is because funding from Shell, not only be helpful financially to continue the research and development (especially since the economic downturn from September 2008), but also an acknowledgement from Shell to choose them from thousands of institutions worldwide.

Collaborate with Shell can be shined by Shell's reputation, towards upbringing their capability, gain wider recognition and higher peer reviews (halo effects of Shell). These institutions are proudly announced their respective projects with Shell, declared through their websites, promoting their expertises and signify their outstanding expertises which led to be chosen by Shell.

Fourth, Shell as the funder, is aim to search for potential findings which could lead to commercial opportunities. Besides, the funding is also building its image as socially

361 The six universities partnered with Shell in 2G biofuels R&D are: [1]The Massachusetts Institute of Technology (MIT), US; [2]The University of Campinas (Unicamp), Sao Paulo, Brazil; [3]The Institute of Microbiology, Chinese Academy of Sciences (IMCAS), Beijing, China; [4]The Qingdao Institute of Bioenergy and Bioprocess Technology, Chinese Academy of Sciences (QIBEBT), Qingdao, China; [5]The Centre of Excellence for Biocatalysis, Biotransformations and Biocatalytic Manufacture (CoEBio3) based at Manchester University, UK; and [6]The School of BioSciences Exeter University, UK. The announcements can be found from Shell's website, media, as well as respective six universities' websites.

concern[362], provides financial support to these institutions for knowledge generation. The Executive of CO_2 Abatement Project Team from the interview responded: “We always interested in new ideas. Things can be done in a better way, effective and economic. Our recent announced researches with six academic institutions are the evidence.”

According to Sweeney: “Shell’s in-house biofuels R&D is long standing and globally coordinated. We know that adding to our knowledge through genuine and nimble partnerships with top experts worldwide, will be critical to speed and success in the fast moving area of biofuels. On the other hand, Professor Nick Turner, Director of CoEBio3, from The University of Manchester welcomed Shell's funding and responded: “Biotechnology has traditionally been the preserve of the pharmaceutical and fine chemical industries, but it is poised to expand dramatically over the next few years into energy industry. CoEBio3 is excited at the prospect of working with Shell in this innovative programme to further existing techniques in the field and develop new, groundbreaking technology (for biofuels)” (Shell, 17 September 2008).

These six universities research collaborations are one of Shell's expanded R&D strategies in the NGB development, which will complement Shell’s ongoing biofuels' R&D with other six business partners. The other six research projects are objective oriented, specifying the types of technology required[363]. Through these six universities research agreement, Shell is seeking more innovative/fresh ideas for new high yield feedstocks, and new process technology, aimed at increase the efficiency of **the** NGB production.

(f) Shell JV with Codexis, 2009

On 10 March 2009, Shell and Codexis[364] announced an expanded agreement, (previous agreement was in November 2007) to develop enzymes that could accelerate the commercialisation of the 2G biofuels. Shell also increased its equity stake in Codexis and will take an additional seat on the company’s board. After more than a year of collaboration (November 2007-March 2009), Codexis's enzyme has demonstrated positive results on wheat straw bioethanol production through the demonstration plant in Ottawa (Shell, 10 March 2009).

From 2009 onwards, both companies are striking for full commercial scale production. This is further explained by Alan Shaw, Codexis President and CEO: “Codexis’ biocatalytic technology provides a discovery pathway for development of next generation biofuels from renewable resources. In the first year of our collaboration, we have demonstrated the ability to solve complex technical

362 The big corporate like Shell is always being expected by the public, to perform some contributive activities for the social well being. From these R&D projects, Shell as funder, has provided employment opportunity for researchers, open more research opportunity/scholarships for new researchers, allows cross disciplinary collaborations taking place from different departments in the university (which previously has no significant cooperation or limited connection).

363 Shell-Iogen for cellulosic bioethanol; Shell-Choren for BTL; Shell-HR BioPetroleum for marine microalgae biodiesel; Shell-Virent on sugar-to-biogasoline, Shell-Codexis for enzyme and Shell-Cosan for sugarcane.

364 Codexis technology creates enzymes that make new industrial process possible and make existing processes faster, cleaner and more efficient towards commercial scale (Codexis Inc, 2009).

challenges to successful biofuels development. In just over two years, our biofuels collaboration with Shell has grown from a pilot project to a programme which can to create commercial scale biofuels from non-food sources” (Shell, 6 November 2007; Shell, 10 March 2009).

Cellulose is the molecules that make up plants' cell walls, can be found in a number of forms in biomass. To break down the cellulose, enzymes are needed to act as a catalyst for the fermentation process, and Codexis's enzyme provides a solution for bioethanol conversion. This is supported by interview: “Biomass has high energy content. Yet, it contains a lot of water which we must get rid of. Nature makes biomass difficult to break down. Shell is working with Codexis to develop enzymes which can improve efficiency and help lower production costs,” said the Quality Engineer from the interview.

Further explained by Sweeney: “Breaking down and converting biomaterial/biomass into transport fuels is complex. This research works into enzymes for more efficient conversion and better biofuels, is part of Shell accelerating its drive to make next generation biofuels a commercial reality” (Shell, 6 November 2007; Shell, 10 March 2009). Currently, Codexis is working with Shell and Iogen to enhance the efficiency of the cellulosic bioethanol production, by shorten the timeline to its full-scale commercial deployment. The new agreement also continues the collaboration to investigate other feedstocks, researching new enzymes to convert biomass directly into components similar to gasoline and diesel, while Codexis will expand researches at centres in the US and Budapest (Shell, 10 March 2009).

(g) Shell and Cosan sign MOU to Form JV in Brazil

Shell and Cosan[365] announced on 1st February 2010, they have signed a “Non-Binding Memorandum of Understanding” (refer appendix 6.2.2), intended to form a circa USD12 billion 50-50 JV in Brazil for the production of bioethanol, sugar and power (co-generation of electricity from sugarcane); together with the supply, distribution and retail of transportation fuels. Under the terms of the MoU, both companies contribute certain assets to the JV, Shell would contribute a total of USD1.625 billion in cash, payable over two years. Mark Williams, Shell’s Downstream Director welcomed this JV: “Joining with Cosan is a way to grow the role of low carbon, sustainable biofuels in the global transportation fuel mix” (Shell, 1 February 2010).

Responded to the environmentalists about negative implications in threatening rainforests by expanding sugarcane plantations, Shell spokeman responded through Guardian: “Sugarcane for bioethanol uses about 1% of Brazil's arable land (354m hectares). None of Cosan's farms are anywhere near rainforests” (Guardian, 1 February 2010). Besides, the company has developed sugarcane harvest satellite monitoring software, which provides better decision-making on land use and precise estimates on production (Cosan S.A., 2010). The two parties now maintaining

365 Founded in 1936 in Brazil, Cosan now has twenty-three production facilities, four refineries and two port terminals. As a producer of sugar, ethanol and electric energy (produced from sugarcane), Cosan is the third largest sugar producer in the world, the fifth largest ethanol producer in the world (Cosan S.A., 2010).

exclusive negotiations towards a binding JV agreement, which shall be subject to final transactional documentation, due diligence, agreement between the two parties on sustainability issues, regulatory approvals and respective corporate approvals (refer appendix 6.2.3) (Shell, 1 February 2010).

The JV enables Shell and Cosan to establish a scalable and profitable position in sustainable biofuels. There are two reasons backed for this decision. First, Brazilian sugarcane bioethanol technology is one of the most efficient commercial scale solutions, while Brazil is the most efficient ethanol producing country in the world (Financial Times, 1 February 2010). Second, the NGB biofuels would need another five to ten years before they could be produced at commercial scale. Hence, with the corporate intention not to lost the market share from the current biofuels business, while can control bioethanol supply chain from farm to kiosk, Shell has this JV established to secure its position as the near-term and long-term biofuels producer and supplier.

Appendix 6.2.1 Manpower Used in Microalgae Harvesting

The most common harvesting processes are flocculation, microscreening filtration and centrifugation which employ manpower.

(a) Flocculation is a method of separating microalgae from the medium by using chemicals to force the microalgae to form lumps. The main disadvantage of this separation method is the additional chemicals are difficult to remove from the separated microalgae, probably making it inefficient/uneconomic for commercial use. The cost to remove these chemicals may be too expensive (Oilgae, 2009a).

(b) Microscreening filtration is carried out commonly on membranes of modified Cellulose with the aid of a suction pump. The greatest advantage of this method as a concentrating device is that, it is able to collect microalgae/cells of very low density. However, concentration by filtration is limited to small volumes and leads to the eventual clogging of the filter by the packed cells when vacuum is applied.

Several methods have been devised which avoid these problems. One involves the use of a reverse-flow vacuum in which the pressure operates from above, making the process gentler and avoiding the packing of cells. This method itself has been modified to allow a relatively large volume of water to be concentrated in a short time (20 liters in 3 hours). A second process uses a direct vacuum but involves a stirring blade in the flask above the filter which prevents the particles from settling during the concentration process (Oilgae, 2009b).

(c) Centrifugation is a method of separating microalgae from the medium by using a centrifuge to cause the microalgae to settle to the bottom of a flask or tank. Centrifugation and drying are currently considered too expensive for small scale use (Oilgae, 2009c).

Appendix 6.2.2 Memorandum of Understanding

It is a common practice for an MOU to be part binding and part non-binding. Whether an MOU is binding is a question of general contract law. A contract will be binding if there is offer/accepted/intended to be legally bound and consideration. For

an MOU, what is particularly important is the intention of the parties at the time of signing the MOU. For commercial contracts, there will be a strong presumption that the parties intend to create a legally binding contract if the terms of the MOU are clearly defined and supported by consideration. For this reason, if the parties do not wish to be bound by the MOU until the execution of formal documents, then the parties must state clearly and unambiguously their intention not to be bound. This may be achieved by using the words "subject to contract", or to include a clause in the MOU stating which provisions of the MOU are binding and which are not.
Source: Mallesons Stephen Jaques. 2002.

Appendix 6.2.3: Corporate Approvals Between Shell and Cosan

Cosan and Shell would contribute the following to the JV

Cosan	Shell
(a) Sugarcane crushing capacity: currently 60 million tonnes per annum from 23 mills (b) Ethanol production capacity: currently 2 billion litres per annum and ethanol logistics assets will increase up to 4-5 billion litres a year. (c) Co-generation: seven existing plants, two under construction and a further three to be built in the next three to four years. (d) Brazilian downstream assets, including 1730 retail sites and supply and distribution assets. (e) Controlling share in ethanol trading company (f) Net debt of approximately $2.5billion.	(a) Brazilian downstream assets, including 2740 branded retail sites, supply and distribution assets, and the aviation fuel business, including the one recently acquired from Cosan. (b) Shell's 50% share interest in Iogen Energy (c) Shell's 14.7% share interest in Codexis (d) $1.625 billion in cash, paid over two years.

Source: Shell. 1 February 2010.

Appendix 6.2.4 Shell's Sustainable Sourcing Policy (SSP)

Shell's SSP (2007) is a policy enforces its suppliers, pressing for sustainable biofuels feedstocks and productions. It encompasses statements, not only enlists Shell's responsibilities link to its 1G biofuels suppliers, but also an evidence showing Shell's commitment on the social responsibility and environmental concern. In a simpler description, the SSP has elaborated the code of conduct for biofuels' feedstocks farming and production. Examining the SSP (2007), the key component of Shell approach to sourcing sustainable biofuels is engaging with both its stakeholders and suppliers.

(a) Commitment to Stakeholder Engagement
(i) Shell is working with environmental groups, governments, suppliers and industrial partners on standards for producing energy crops sustainably and supports an industry wide approach on sustainable biofuels productions, both at the global and local level.
(ii) Shell is playing role in shaping and promoting sustainability standards and is participating in multi-stakeholder initiatives such as the various Roundtables.
(iii) Shell is engaging with suppliers and stakeholders to work towards reducing biodiversity impacts and build capacity towards the sustainable production of biofuels feedstocks.

(b) Engagement with Suppliers
(i) Shell is working with its suppliers to create awareness about sustainable sourcing

and to work towards a more sustainable supply chain.
(ii) Shell is working with its suppliers to incorporate clauses in supply contracts that will seek to ensure that biofuels are not linked to:
-recent clearing of areas of high biodiversity value (forests/jungles, wetlands and food farms/plantations), which previously is not for biofuels (Shell, 2007b)
-violation of human rights (including child/forced labour) (Shell, 2007c)
(iii) Shell encourages its suppliers to establish a supply chain traceability system; through the reporting from the suppliers on monthly basis on quantify, source of supply, location and types of feedstock used.
(iv) If any suppliers wish to supply to Shell, they must commit to work with Shell to develop a more sustainable supply chain. It depends on which stages the supplier is in. Starting with communication for information sharing, guidance and advice will be provided, then the inspection on biofuels farm/plantation is necessary to assessment the sustainability criteria. If match, finally supplier contract will be awarded.
(v) Shell engages with suppliers to review progress on a regular basis and reserves the right to conduct independent audits of its suppliers and to terminate contracts.
Source: SSP Shell. 2007.

Appendix 6.4.1 Shell and Ferrari
Within Shell and Ferrari, it shows the symbiotic collaboration between them. Shell’s works covering fuels, engine lubricants and transmission fluids, where the Ferrari engines provide a testing ground for constant improvements to the Shell road products (Shell, 2009d). Therefore, Ferrari’s approval and endorsement is important recognition for Shell.

As Ferrari engineers devote their time and energy to developing the F1 cars, technical partner Shell dedicates its expertises in building the portfolio of products which contribute to success on the track. The Shell facility in Maranello allows Shell scientists and technicians to work hand-in-hand with Ferrari engineers during any development stage in the car’s development, to ensure that the fuel design is optimised for maximum performance and reliability. Shell takes an integrated design approach alongside Ferrari to the F1 programme and the challenge is to improve the development rate, pushing the boundaries of F1 fuel and lubricants to a more competitive level (Shell, 2009d).

Appendix 6.4.2 Shell and Ducati
Within Shell and Ducati, over ten years, Shell's technical partnership with Ducati has been a successful collaboration in motor sport. Working with the Ducati team, Shell is learning from the extreme testing environment of the race track contribute to providing bikers with high performing fuel products such as Shell V-Power road fuel and Shell Advance oil. The results have been constant across the ten-year relationship, with Shell’s continued goal to provide Ducati with reliability, whilst optimising the power output from the bike.

Jörg Landschof, Fuel Development Expert, Shell Global Solutions explained, “The target is always to increase the engine efficiency, by getting maximum possible power at minimum possible consumption. Sometimes this can be a difficult task. The Shell V-Power fuel blend is constantly being developed as we continue to learn by racing these high revving, ultra-powerful engines. The knowledge gained at the track for fuels and lubricants is then used in Shell V-Power road fuels and Shell Advance lubricant to the benefit of the customer" (Shell, 2009e).

Shell focuses on maximising the power provided by the Shell V-Power racing fuel, while developing Shell Advance Ultra Racing Oil to further reduce friction in the engine and ensure the greatest performance from the Ducati bikes. Claudio Domenicali, Ducati Corse CEO and Ducati Motor Holding product director added, "To celebrate ten years of collaboration with Shell and to be able to continue to count on a partner that is so dedicated to top-level technical development and research. Shell develops oils and fuels for the highest levels of motor sport competition, such as Formula 1, MotoGP and Superbike, and then transfers the experience gained into creating products for the road, a philosophy that we in Ducati have always adhered to and which further strengthens the link between our two companies" (Shell, 2009e).

Today, Shell's technical partnership with Ducati has become one of the successful in motor sport-with seven World titles and over 150 wins collected during its first 10 years. At the core of this relationship lies a common passion for technology: Ducati develops its race and road bikes, while Shell works to design high-performing fuel and lubricants technology for the benefit of bikers.

Appendix 7.1.1 BP and Shell Next Generation Biofuels Development

Supported by four publications[366], there are six oil companies[367] embarking on the NGB R&D. Up to date (31 December 2010), the oil companies operating in the UK, have not produced their own biofuels yet, as they are purchasing biofuels from the international market.

(a) Chevron

Chevron is a US based company, which has more than 1100 petrol stations (Texaco, 2010a) operating in the UK under the brand name of Texaco. Due to the limited information could be found from the Chevron website, added with no response from the HQ in Gloucestershire after letters/emails sent for invitation to participate in my research, Chevron has not be selected as one of the case study.

Up to date, Chevron has seven R&D projects on going:

(i) Chevron-Georgia Institute Technology formed a strategic research alliance for cellulosic biofuels in 2006 (Georgia Institute of Technology, 3 July 2006).

(ii) Chevron funds University of California Davis for rice straw/agricultural waste biofuels in 2006 (University California Davis, 19 September 2006).

(iii) Chevron and US National Renewable Energy Laboratory enter collaborative research for cellulosic biofuels in 2006 (National Renewable Energy Laboratory, 4 October 2006)

(iv) Chevron-Weyerhaeuser announced letter of intent for cellulosic/lignin conversion into biofuels in 2007 (Weyerhaeuser Company, 12 April 2007).

(v) Chevron-Texas A&M University into strategic research alliance for conversion of

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366 [1]Krauss, C. 26 May 2009; [2]Mollman, S. 23 August 2009; [3]Chazan, G. 19 October 2009; and [4]Nelson, T. 3 November 2009.

367 [1]BP (UK), [2]Chevron (US), [3]Exxon Mobil (US), [4]Petrobras (Brazil), [5]Shell (Netherlands) and [6]Total (France).

non-food crops to biofuels in 2007 (Chevron, 29 May 2007).
(vi) Chevron and US National Renewable Energy Laboratory enter collaborative research for algae biofuels in 2007 (Chevron, 31 October 2007).
(vii) Chevron enters agreement with Solazyme for algae biofuels in 2008 (San Francisco Business Times, 22 January 2008).

(b) Total
Total is a French company and recently embarks on biofuels R&D. It established joint venture with Gevo to develop biobutanol/isobiobutanol (Total, 2009; Gevo, 2009). Butanol/Isobutanol is a 2G bioalcohol, created from the fermentation of biomass such as corn, grass and agricultural waste. Total and Nestle Oil have discontinued their biodiesel project on 6 February 2007 due to high cost needed for the investments (Nestle Oil Corporation, 6 February 2007).

(c) Exxon Mobil
On 14 July 2009, Exxon Mobil has established JV with Synthetic Genomics on the algae biofuels research (ExxonMobil, 14 July 2009; Synthetic Genomics, 14 July 2009).

Both Total and Exxon Mobile are the new comers into the NGB R&D. Because the dates of announcement were beyond my data collection (ended in March 2009), both Total and Exxon Mobil have been excluded from the research.

(d) Petrobras
Petrobras is a Brazilian oil company. Due to geographical concentration of Petrobras in Brazil, it has no significant business investment in the UK, Petrobras also has been exclude from the research.

Appendix 7.1.2 Technical Criteria of Biofuels
Biofuels cover two types of products: bioalcohol[368] and biodiesel. They are derived from biomass, living organisms, or their metabolic by products/wastes (BBC, 24 January 2007). Biomass is an organic plant material containing energy obtained from sunlight that the plant stored when it grew. This stored energy can be converted into liquid fuels. Besides, organic wastes which contain carbon compounds can be processed in order to produce biofuels. Biofuels manufacture is based on processes of fermentation and transesterification, which convert the carbon held in organic plant/animal matter, to other carbon based molecules which have suitable properties for serving as liquid transport fuels.

(a) Bioethanol
It is the most common of ethyl alcohol produced by the action of microorganism enzymes in the fermentation of sugars/starches[369]. The starches are hydrolysed using enzymes, fermented, distilled and then dehydrated to give 95-97% bioethanol (Knott, 2007; BP, 2007a). The technical characteristics of bioethanol are shown below:

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368 the current bioalcohol used in the market is bioethanol. It is foreseeable that BP's biobutanol would be available after five years from 2008.
369 *found in plants such as cereals, potatoes, corn, cassave, sorghum, wheat and sugarcane.*

Table 7.1.1: Comparative between Bioethanol (Be) and Petrol (P)

Characteristics	Be	P	Contributions
Octane number[370]	98	80	Be is safer than P which ensures drivers safety.
Vapour pressure	Lower evaporative emission, vapour density of 1.59	Higher evaporative emission, vapour density 3-4	Be provides better fuel economies to minimise fuel wastage when drivers are refuelling outdoor.
Flammability in air	Lower, with flash point -5°F	Higher, with flash point -45°F	Be is safer, which to reduce the severity of vehicle fires. This could ensure user safety.
*Heating values	21.2-23.4MJ/litre	30.1-34.9MJ/litre	P generates higher energy than Be. This means Be has only 67% of the P's energy content for the same volume. This is the weakness of Be and results in a lower fuel efficiency.
*Energy content, used in the *internal combustion engines (*ICEs)	Required 20% more than P	Normal use	Be is uneconomical. Flex fuel[371]/biofuels cars are needed as they have engines with a higher compression ratio. While used in the existing ICEs this would cause more energy losses. This is the weakness of Be, which results in a lower fuel efficiency.
GHG emissions	If E100 is used, this causes: (a) the total elimination of aromatic hydrocarbons (benzene) (b) cutting sulphur, CO_2, CO, Lead ambient. (c) Increase aldehyde emissions[372] (d) Blue flame with no carcinogenic compounds found	(a) Smoke from burning P is black and has toxic components (b) carcinogenic compounds found	Be's emissions are cleaner than P. Be contributes to the environmental benefits for combating climate change and reduce air pollution/GHG emissions.
*Water affinity	High and water soluble (hydrophilic)	Non water miscible and insoluble (hydrophobic)	Be's water affinity could bring problems to the ICEs. This could cause components of ICE to rust. This is a weakness of Be and result in a lower social confidence on a higher percentage of bioethanol use.
General characteristics	Renewable	Fossil	Renewable of bioenergy. This is the strength of Be, contributing to the political, economic, social and environmental benefits[373].

Source: The researcher utilised Goldemberg (2008) framework and made further analysis.
* prioritised in the NGB research.

370 The anti-knock properties of a liquid motor fuel. The higher the number, the less likely the possibility of the fuel detonating (World Encyclopedia, 2008).
371 Flex-fuel motors are capable of running with blends from pure petrol to E100. The technology is based on sensors in the fuel system that automatically recognises the ethanol level in the fuel. The engine's electronic control unit then self-calibrates for the best possible operation; if ethanol is not present, the engine will self-calibrate to gasoline-only operation. The process is instantaneous and undetectable by the vehicle driver (Goldemberg, 2008).
372 Acetaldehyde from bioethanol is less aggressive to human health and the environment than formaldehyde produced when gasoline is burned (Goldemberg, 2008).
373 Political (energy security), economical (generate more employment opportunities, enable wealth generation for oil companies in renewable energy profile), social environmental benefits (in reducing GHG/CO_2 emissions towards better public health and slow down the climate change implications)

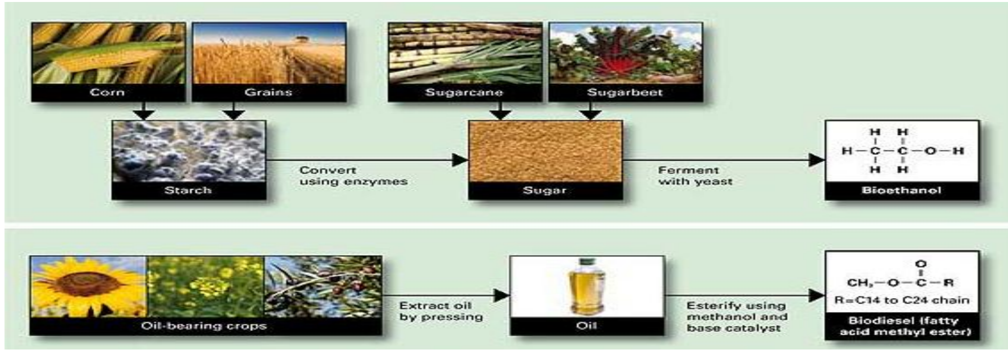

Figure 7.1.1: Basic Process for Bioethanol and Biodiesel
Source: BP. 2007a.

There are some good characteristics of bioethanol when compared with petrol. However, there are three critical liabilities[374] to be found, which have captured the oil companies' attention in order to overcome bioethanol's limitations. Through ongoing R&D[375], BP and Shell aim to breakthrough these technical limitations, and are seeking a higher performance bioalcohol. Currently, bioethanol is produced from more than thirty countries, with the US and Brazil topping the list and together account for some 90% of world supply[376].

(b) Biodiesel

Biodiesel manufacturing is based on the extraction of oils from plants (such as soybeans, rapeseed, sunflowers and palm oil), animal fats/tallow, used cooking oil and algae. The chemical process used to convert these oils to biodiesel is called transesterification, and the resulting biodiesel is chemically identified as fatty acid methyl ester (FAME). Methanol is used in conjunction with an appropriate catalyst under controlled conditions, which allows the oil based material to be transesterified to a FAME. The FAME then undergoes a series of washing steps before finally being distilled to produce biodiesel which meets the European standard (Argent Energy, 2009).

Biodiesel has combustion properties similar to mineral diesel, and can be blended with mineral diesel used in ICEs. It is less toxic than table salt and as biodegradable as sugar (Argent Energy, 2009), which is good for public health and environmental impact. The technical characteristics of biodiesel are shown below:

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374 Low heating values, low energy content- bioethanol energy content accounts only 2/3 of gasoline, and a high water affinity.

375 BP JV with DuPont researching on biobutanol, while Shell joint R&D with Virent to convert sugar to biogasoline- which will expected to have some similarities of petrol. Both biobutanol and biogasoline will demonstrate better performance than existing bioethanol, with higher energy content and lower water affinity.

376 In 2006, the US produced over 18.5 billion litres of bioethanol; mainly from corn, using about 1/6 of its domestic corn crop to do this and replacing about 2% of the country's gasoline use. In Brazil, which has been making bioethanol since the 1970s, around half of the country's sugarcane crop goes into bioethanol for domestic use and export. In 2006, Brazil produced over 17.8 billion litres, achieving attractive economic efficiencies. In contrast to corn based bioethanol, conversion from sugarcane eliminates the hydrolysis stage. In Brazil, the plant residue, or bagasse, is reused to generate heat and electricity, making the process more cost effective and environmental friendly (Knott, 2007; BP, 2007a).

Table 7.1.2: Comparative between Biodiesel (Bd) and Diesel (D)

Characteristics	Bd	D	Contributions
Cetan index[377]	49-62	46-53.6	Bd is higher than D, and provides a higher combustion efficiency.
Flammability in air	Flash point 120-179°C	Flash point 55-66°C	Bd is safer to reduce the severity of vehicle fires. Thus this could ensure user safety.
*Used in the existing ICEs	Strong solvent properties to natural rubber and soft plastic	Normal use	High concentration of Bd (equivalent to B20 or more) could cause problems to ICEs engine components[378]. This is a weakness of Bd, which would prohibit a higher percentage use and result in lower social confidence.
GHG emissions	In B100, render to the (a) cut of Sulphur Oxides and Sulphates (major components of acid rain) (b) cutting CO_2 (78.45%), CO (78%), Particular matter (68%), aromatics and unburned hydrocarbons, NO_2	(a) Smoke from burning D is black and has toxic components (b) carcinogenic compounds-Polycyclic Aromatic Hydrocarbons (PAH) found (c) unburned hydrocarbons and nitrogen oxides (ozone or smog forming precursors) found (d) Sulphur oxides and Sulfates (major components of acid rain) found	Bd's emissions are cleaner than D and helps in combating climate change and reducing air pollution/GHG emissions.
General characteristics	Renewable, biodegradable, non toxic, low sulphur[379].	Fossil, toxic.	Renewable of bioenergy contributes to the political economical, social and environmental benefits[380].

Source: Yuksek, et al. 2009; NREL, 2008; von Wedel, 1999.
* prioritised in the NGB research.

There are some good characteristics of biodiesel when compared with diesel. However while one major problem (strong solvent properties) has captured consumers' attentions. A case study was conducted by von Wedel (1999) on a boat using 100% neat biodiesel. After four years of operations, the fuel lines and gaskets were seriously affected. They turned out to be sticky, soften and swell, causing fuel

377 A number that provides a measure of the ignition characteristics of a diesel fuel. The higher a cetane number is, the better combustion efficiency it will provide (Daintith, 2009).
378 Rubber fuel lines, seals and gaskets on ICE fuel tanks may slowly deteriorate in the presence of higher concentrations of biodiesel.
379 Bd sulphur content is 7.46-10mg/kg, while D sulphur content is 1471-7000mg/kg.
380 Political (energy security), economical (generate more employment opportunities, enable wealth generation for oil companies in renewable energy profile), social environmental benefits (in reducing GHG/CO_2 emissions towards better public health and slow down the climate change implications).

to drip from the connections.

This caused the rubber fuel line between the primary filter and the fuel pump on the sailboat engine to became tacky. Thus, the solvent effect found in biodiesel-equivalent of more than 20% (B20 and above), could reduce public confidence and prohibit a higher concentration of biodiesel use. However, it could be reduced through three ways: First, lower the biodiesel blend to less than 20%. Second, to replace ICEs' lines and gaskets with modern synthetic hoses and seals. However, this replacement would require personal investment by the consumer. Third, a using flex fuel/biodiesel engine which can run on neat biodiesel. This last option would require a much higher investment.

7.1.3 Biofuels and Carbon Neutrality

The mechanisms of biofuels in reducing CO_2 take place in two ways: Firstly, when they are mixed with petrol/diesel, this blend can reduce nearly 2.5-4%[381] of CO_2 emission from the tailpipe.

Secondly, it is about the natural carbon neutrality. The vegetations (feedstocks) are growing under the photosynthesis mechanism and could capture CO_2 from atmosphere, exhale O_2 and produce yield in a biological way (Figure 7.1.2). Therefore, this makes biofuels stands out as better than other alternative REfT, such as H_2/electricity. No doubt scientific evidence validated both H_2 and electricity can significantly reduce the CO_2/GHG emissions from the tailpipe, yet they do not have the biological capability for carbon neutrality.

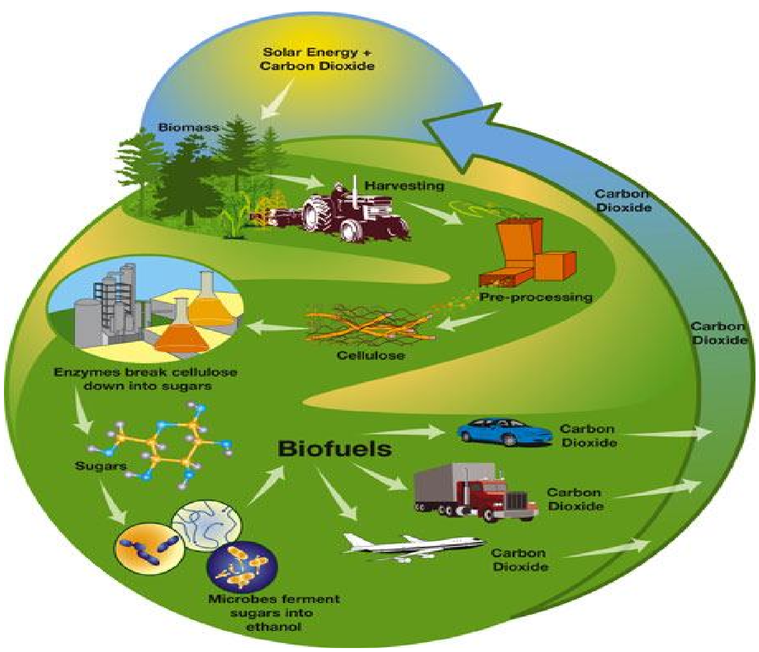

Figure 7.1.2: Biofuels and the Carbon Circle
Source: Interesting Energy Facts. 2008.

381 5% biofuel blend would result in a carbon reduction of around 2.5% (biodiesel) and 4% (bioethanol) (Whatagreencar, 2008).

Appendix 7.1.4 Countries with Respective Biofuels Feedstocks

Table 7.1.3 Countries with Respective Biofuels Feedstocks

Countries	Biofuels Feedstocks
Malaysia	Palm oil
Brazil	Sugarcane, sunflower, soy, castor bean
India	Jatropha
Pakistan	Sugarcane
Thailand	Sugarcane , cassava, palm oil, coconut, jatropha
China	Cassava , jatropha, wheat, sweet sorghum, corn
Indonesia	Palm oil, sugarcane, cassava, jatropha
Cambodia	Jatropha
Costa Rica	Palm oil
The US	Corn, soy
France	Sugar beet, rapeseed, sunflower
Germany	Rapeseed, cereals
Spain	Barley, wheat
New Zealand	Oilseed
Canada	Wheat, corn

Source: Collected by the researcher

Appendix 7.1.5 The Green Economy

Green economy is a growing economic development, in contrast to the existing "black" economy-based on fossil fuels (coal, petroleum and natural gas). It is rooted on the knowledge of ecological economics, which aimed at addressing the interdependence of human economies and natural ecosystem with the adverse impacts of human economic activities on climate change/global warming. In the midst of the global economic crisis since 2008, the UNEP called for a Global Green Deal, where governments all over the world are encouraged to support its economic transformation to a greener/low carbon economy.

The activities in the green economy includes green energy generation based on RE, to substitute for fossil fuels; energy conservation for efficient energy use-which sectors include efficient building constructions, sustainable transport, sustainable agriculture, freshwater and ecological infrastructure. The green economy is considered being able to both create new jobs, ensure real and sustainable economic growth, and prevent environmental pollution, global warming, resource depletion and environmental degradation (United Nations Environment Programme, March 2009).

Appendix 7.3.1 Food-Fuel Competition and Biodiversity Threatened

To have a closer look at these two systemic risks, this discussion is mainly focused on the US. This is because, there are more articles found about the US biofuels, which could support the discussions further. Besides, the US, as one of the world largest biofuels producers, demonstrates the complete cycle of biofuels supply chain: from growing feedstocks, to production and finally international trading. With the biodiversity threatened home environment, the food-fuel competition caused by the US, impacted not only the domestic market, but also has pervaded cross-borders.

(a) Food-Fuel Competition
The current international/national biofuels policies are favoured at grain based biofuels (1G biofuels). As the 1G biofuels increasingly impinge on the supply of corn and soy, a food-fuel competition broke out. This then drove up the prices of staple foods in the US and in other parts the world.

In the US, the explosive growth of the biofuel sectors and their demand of raw stocks for production triggered increases run ups in the prices of corn, grains, oilseeds and livestocks/poultry. Eventually, these higher costs also appeared in the prices of frozen/canned vegetables and processed meat. Besides, rising feed prices (mainly soy and corn) also hit the livestock and poultry industries. Some agricultural economists predict that, Iowa's pork producers could be driven out of business as they are being forced to compete with ethanol producers for corn/soy (Johnson and Runge, 2007). Critics note that, both domestic and international consumers of food and livestock fed with grains faced abrupt rising prices in 2007/8. This then being repetitively reported over the BBC News (4 March 2008; 29 May 2008; 15 October 2008), “The era of cheap food is over!”

In the rest of the world, the demand for biofuels produced many negative effects. In January 2007, due to the rise in the US of corn prices from USD2.80 to USD4.20 in less than four months, the price of tortilla flour in some parts of Mexico rose sharply. The reason for this was, 80% of Mexico's corn is imported, which accounts 1/4 of its consumption are from the US (BBC News, 1 February 2007). The implications were daunting, when the World Bank report researched by Mitchell (8 April 2008; 2008) revealed: from January 2005 until February 2008 world maize prices +131%, wheat prices +177%, and rice prices +62%. From June 2006 until February 2008 world palm oil prices +165%, soybean oil prices +175%, coconut oil +153%, palm kernel oil +137% and groundnut oil +111%.

This was particularly hurtful to the world poorest consumers. The OECD-FAO (2007) issue an outlook for 2007-2016, stating that biofuels had introduced global structural shifts in food markets, which would raise food costs during the next ten years. For the 2.7 billion people in the world living on the equivalent/less than USD2 per day; and the 1.1 billion surviving on less than USD1, even marginal increases in the cost of staple grains can be devastating.

According to Johnson and Runge (2007) calculations, filling a 25 gallon tank of a sport utility vehicle with pure ethanol would require more than 450 pounds of corn, which is enough calories to feed one person for a year. Added by Vidal (22 January 2010), 90 million tonnes of the US grain used to produce bioethanol in 2009, was enough to feed 330 million people for one year at average world consumption levels. What we can see here, is the enormous volume of gains required by the ethanol industry sent a shock wave through the food system. This is the cruel competition between mobility and humanity, where biofuels are believed to be bringing more harm than good.

(b) Biodiversity Threatened

If substantial additional acres are needed for corn, then the land will have to be pulled from other food farms, as well as other environmentally fragile areas. In Minnesota, according to Johnson and Runge (2007), land diverted to corn to feed the ethanol maw has reduced the acreage planted to a wide range of other crops, especially soy. Searchinger et al. (2008) asserted that US biofuels production on agricultural land has displaced existing agricultural production, causing land-use change leading to increased net GHG emissions. Then Maynard (1 March 2007) stresses that, when food and fuel are competing for farmland, then food prices will rise drastically and the poor will suffer, as well as the rainforests.

On the other hand, Augustyn (2007) describes the impact of forest fires to clear land for oil palm plantations in Indonesia. Even though palm oil holds great promise as biodiesel, the plantations have displaced natural ecosystems and destroyed habitat for numerous species, as well as for the indigenous people. A team of UK scientists suggested that, reforestation and habitat protection was a better option as forests could absorb up to nine times more CO_2 than the production of biofuels could achieve on the same area of land. Righelato (1 March 2007) reminds us that, when forests are cleared, they no longer serve as carbon sinks. Thus, deforestation adds to the global warming problem, and it may take a century for the benefit of biofuels to show itself.

Appendix 7.3.2 BP and Shell S*trategies to Deal with the Systemic Risks*

Apart from complying with the RFA stringent "Carbon and Sustainability" monthly reporting system, most of the information released through BP and Shell websites[382] are describing their participations in various roundtables, thus demonstrating their commitments for the G&S biofuels supply. Besides, information about *the* ongoing NGB R&D projects is also published. These messages are clear, to show their dedications for G&S biofuels and their efforts to develop *the* NGB-which can counterbalance the limitations of the 1G biofuels, and could eliminate the two systemic risks from reoccuring.

382 appear as newsletters, annual report and internal circulated magazines

Table 7.3.1 BP and Shell Strategies

Types of R&U	Strategies adopted	
	BP's approach	Shell's approach
1. Technology on socio-environmental implications		
i. Food-fuel competition	i. to resolve food-fuel competition -Invest in large scale Jatropha plantations, as a non-food biodiesel feedstock. -Invest in the 2G biofuels (energy grass) R&D, as a non-food feedstocks.	i. to resolve food-fuel competition -Invest in the 2G biofuels R&D (wheat straw, BTL, biomass to biogasoline), as a non-food feedstocks.
ii. Land competition	Not action taken.	ii. to resolve land competition -Invest in the 3G algae biofuels R&D, through sea farming technique.
iii. Ambiguity of carbon saving	iii. to strengthen the claims of carbon saving -JV with Tropical BioEnergia for sugarcane (because sugarcane can achieve 90% farm-to-wheel CO_2 reduction). -Invest in the 2G biofuels (energy grasses) R&D. (because energy grasses have the potential to deliver GHG reductions up to 80-90%).	iii. to strengthen the claims of carbon saving -JV with Cosan for sugarcane (because sugarcane can achieve 90% farm-to-wheel CO_2 reduction). -Invest in the 2G/3G biofuels R&D (because energy grasses or algae have the potential to deliver GHG reductions up to 80-90%). -SSP execution to promote good agriculture practice along biofuels value chain by minimising energy input, and thus to reduce CO_2 emissions.
iv. The 1G biofuels threatening biodiversity	iv. to resolve biodiversity threatened -Complies with the RFA Meta & Qualifying standards, and reports to the RFA every month with higher transparent data. -Roundtables participations.[383]	iv. to resolve biodiversity threatened -Shell complies with the RFA Meta & Qualifying Standards, and reports to the RFA every month with higher transparent data. -Enforced SSP to its biofuels suppliers/contractors. -Roundtables participations.

Source: Summarised by the researcher

Appendix 7.3.3 Independent Organisations to Disseminate Biofuels Information

-The WorldWatch Institute is an independent research organisation. Its three program areas include Climate & Energy, Food & Agriculture and Green Economy. Since 1974, Worldwatch's interdisciplinary research is based on science and focuses on the challenges that climate change, resource degradation and population growth pose for meeting human needs in the 21st century. WorldWatch seeks solutions to intractable problems, emphasising a blend of government leadership, private sector enterprise,

383 Utilise the collective strengths/representations of roundtables to establish the P&C requirements for a sustainable biofuels business, to reduce the public pressure.

and citizen action that can make a sustainable future a reality. Based in Washington, D.C., WorldWatch research is disseminated in over 20 languages through innovative use of print and online media (WorldWatch Institute, 2009). These publications include: Better than corn (8 October, 2007), and Time to get smart on biofuels (18 February 2009).
-The UK Royal Society is the national academy of science of the UK and the Commonwealth. It is an independent, charitable body which derives its authoritative status from over 1400 Fellows and Foreign Members (The Royal Society. 2009). The publications include: Sustainable biofuels: prospects and challenges (2008a) and Biofuels (2008b)
-The European Biodiesel Board (EBB), is a non-profit organisation established in January 1997. EBB aims to promote the use of biodiesel in the EU, and at the same time, grouping the major EU biodiesel producers (European Biodiesel Board, 2009).
-Nature is the foremost weekly scientific journal and is the flagship journal for Nature Publishing Group (NPG). Launched in 1869, it develops publication arising from new technology and serves a growing audience of readers. NPG publishes journals and online databases across the life, physical and applied sciences and clinical medicine. Content encompasses daily news from journalists, expert opinion and practical methodology, and more high impact research and reviews (Nature.com, 2009). The publications include: Towards better biofuels (21 June 2007), Energy: Not your father's biofuels (20 February 2008).
-Biofuels Digest covers producer news, research, policy, policy makers, conferences, fleets and financial news. The Daily Biofuels News Digest is one of the most widely read biofuels daily in the world and has more than 240,000 references in Google with readers in more than 200 countries. So far, BiofuelsDigest.com has 34,200 monthly visitors and the Biofuels Digest daily e-newsletter has more than 12,900 subscribers spread over more than 7,000 companies (Biofuels Digest, 2009).

Appendix 7.4.1 The Roundtables in Shaping Green and Sustainable (G&S) Criteria for Biofuels

Apart from reporting to the RFA, BP and Shell are bearing more responsibility to ensure that emphasis is put on supplying G&S biofuels, not only in the 1G biofuels supply, but also the NGB being developed. These messages have to be delivered across industries, in order to inform related stakeholders such as peers, other exporting regulators, JV partners and social movements/environmentalists. In order to compliment the internal biofuels management approaches (on activities related to the RFA reporting system), the external collaboration is required to strengthen the entire biofuels supply chain. Both BP and Shell understand that, the biofuels sector must be developed in a G&S ways in order to prolong their biofuels business for many decades to come.

BP and Shell are members for four roundtables [384], and have consistent communication with different stakeholders including organisations in the private sector[385], international bodies[386] and local GOs/NGOs[387] in countries where biofuels

384 There are four roundtables: Roundtable for Sustainable Biofuels (RSB), Roundtable on Sustainable Palm Oil (RSPO), the Roundtable for Responsible Soy (RTRS) and the Better Sugarcane Initiative (BSI).
385 Private sectors: BP, Shell, Toyota Motor Europe, Petrobras, Bunge.

are produced. These roundtables provide a platform and a cohesive channel for various stakeholders to share information and make collective/consensual decisions. These various roundtables address many diverse issues that have been raised concerning biofuels production and which not only gain external understanding/support for the respective biofuels stakeholders' involvement, but also for charting the path of G&S biofuels management system internationally for current and future global biofuels trading.

The tangible outcomes from these roundtables are the general principles for G&S biofuels applications and practices (summarised in Table 7.4.1). The RSB is focused solely on the general principles which address twelve common issues. These twelve common issues provide a guide/reference/backbone for other roundtables to develop their respective code of practices. The other three are specifically driven to respective types of feedstocks: palm oil (RSPO with eight principles), soy (RTRS with five principles) and sugarcane (BSI with five principles)-which not only constitute the largest three types of feedstocks used in biofuels[388] production, but also the largest foodstocks consumed by the world's population.

These roundtables are the platforms that pool together different stakeholders, experts, interest groups from different level[389] in order to keep in pace, align and converge different views, opinions, actions, experiences and knowledge towards standards formulation, and for G&S biofuels production principles and practices.

* They are part of the Founding Steering Board members of Roundtable Sustainable Biofuels (RSB).

386 International bodies: WWF International, United Nations Conference on Trade and Development (UNCTAD), National Wildlife Federation, World Economic Forum, UN Foundation, Forest Stewardship Council, UN Environment Programme.

* They are the Founding Steering Board members of Roundtable Sustainable Biofuels (RSB).

387 Local GO/NGO: Swiss Energy Ministry, Fed of Swiss Oil Companies, Keio University, UNICA SugarCane Industry Association Brazil, Energy Centre EPFL, TERI India, Brazilian Environmentalists, Mali Folkecentre, Dutch Ministry of Housing and the Environment.

* They are the Founding Steering Board members of Roundtable Sustainable Biofuels (RSB).

388 apart from corn which does not have its roundtable

389 Local community, national, some from the regional (EU, Asia Pacific) to international (UN).

Table 7.4.1: Summary of Four Roundtables

Roundtable	Roundtable for Sustainable Biofuels (RSB)	Roundtable on Sustainable Palm Oil (RSPO)	Roundtable for Responsible Soy (RTRS)	Better Sugarcane Initiative (BSI)
Principles	twelve	eight	five	five
Criteria	(a) Legality	(a) Compliance with applicable laws and regulations	(a) Legal compliance and good business practice	(a) Obey the law
	(b) Human and labour rights	(b) Responsible consideration of employees and of individuals and communities growers and mills affected	(b) Responsible labour conditions	(b) Respect human rights and labour standards
	(c) GHG emission (d) food security (e) conservation (f) soil (g) water (h) air (i) land rights	(c) Environmental responsibility and conservation of natural resources and biodiversity	(c)Environmental responsibility	(c)Actively manage biodiversity and ecosystem services.
	(j) Consultation, planning and monitoring	(d) Commitment to transparency to provide adequate information	(d) Good agricultural practice.	(d) Commit to continuous improvement in key areas of their business
	(k) Rural and social development	(e) Commitment to continuous improvement in key areas of activity	(e) Responsible community relations	(e) Manage input, production and processing efficiencies to enhance sustainability
	(l) Economic efficiency, technology and continuous improvements	(f) Commitment to long term economic and financial viability		
		(g) Use of appropriate best practices by growers and millers		
		(h) Responsible development of new plantings		

Source: Summarised by the researcher

These roundtables have different levels of stakeholders which gradually build up their substantial reputation and significant influences in the G&S biofuels applications. BP and Shell are the first oil companies to collaborate with other members in these four roundtables, while other the international oil companies still have not participated as members of any of these four roundtables.

Working with world reputable socio, economic and environmental organisations[390] would shade BP/Shell from the international criticisms on the unsustainable biofuels controversy. Since the establishment of the four roundtables and the general principles which have been established respectively from them, there has been significantly lower open criticism heard and reported by the media, compared with the previous media wars accusing the oil companies and regulators acting recklessly to cause these systemic risks. This is a strategic act from BP and Shell, rather than rhetorically promising on the G&S issues abstractly. They have turned their participation in four respectable roundtables as evidence of their actions to the world of their efforts and eagerness to commit G&S biofuels businesses as their current and future business objectives.

Appendix 7.4.2 Sustainability

Sustainability is first defined from the publication of the report "Our Common Future" by the United Nations' Brundtland Commission in 1987. The commission defined sustainability, and in particular sustainable development, as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (United Nations, 1987). In the context of energy, sustainability has come to mean the harnessing of those energy sources:

(a) that are not substantially depleted by their continued use;

(b) the use of which does not entail the emission of pollutants or other hazards to the environment on a substantial scale; and

(c) the use of which does not involve the perpetuation of substantial health hazards or social injustices.

Sustainability indeed is a very broad ideal, according to Boyle (2004). Although a few energy sources can come close to fulfilling these conditions, most fall considerably short of the optimum. This means that, in practice, sustainability is a relative rather than an absolute concept. It is not so much that some energy sources are sustainable and others not. It is more that some energy sources, in certain contexts, are more sustainable than others. Determining the relative sustainability of one energy system vis-a-vis another is usually a complex process, involving detailed consideration of the specific processes and technologies proposed, the context in which they are being used and the differing values and interests of the various parties involved.

To describe the definition of sustainability criteria for biofuels, which covers wider applications, it encompasses three aspects as advocated by the Bioenergy and Energy Planning Research Group (14 October 2009)**:**

(a) Technical criteria: must comply with the existing technical quality standards of

390 WWF International, UNCTAD, National Wildlife Federation, World Economic Forum, UN Foundation, Forest Stewardship Council, UN Environment Programme.

biofuels certification in the EU: EN142140-15376 for seamless distribution infrastructure and engine adaptation. Besides, biofuels must comply with the criteria defined in EU Biofuels Directive and legislation in place of the EU Member States.
(b) Ecology criteria: taking into account the GHGs emission, water footprint, energy inputs, land use/changes, local biodiversity/ecosystems and global impact as a whole from the international trading of biofuels (import and export activities involved from the producing nations to the importing countries);
(c) Social criteria: biofuels must not compete with food or impair food security, must provide non-discriminative working conditions (no force labour, no child labour) and does not manipulate the local communities through resources exploitation, farm land/preserved high value areas (jungle/forest) conversion to biofuels plantation, but must conduct responsible agricultural practices which will safeguard social, economic interests and environmental concerns

Appendix 7.4.3 Feedstocks Yield Comparison
When choosing biofuels feedstocks, people have looked primarily to plants that can be grown in large scale to produce large quantities of biofuels. This is indeed a misconception that "large scale" could guarantee higher outputs. Balancing between "large scale" and "high yield", one of the aims for the NGB R&D which is emphasised on the later. The comparison between large scale and higher yield are indeed different. The related feedstocks with respective yields are shown below:

Table 7.4.2: Biodiesel Feedstocks with Respective Yield Capacity

Feedstocks	Yield (L/ha)	Commercial Usages
Palm oil	4752	Food, cooking oil, medicine
Algae	3000	Non-food, some for medicine, nutrition, abalone feed, fertiliser, pigment, and chemical substance
Coconut	2151	Food, coconut water for drink, coconut milk, cooking oil, nectar and toddy
Rapeseed	954	Animal feed, cooking oil
Soy	554-922	Food, nutrition, cooking oil, flour, infant formula, cattle feed
Peanut	842	Food, cooking oil, flour
Sunflower	767	Cooking oil, livestock feed

Source: Roberts, D. 7 February 2006.

From these seven high yield feedstocks, algae does not fall into the food category. Others have strong connections with food/animal feeds which affect the entire food supply chain. This explains the current NGB aims in finding high yield feedstocks, and where most of the oil companies are embarking on algae R&D. Algae has seven[391] taxonomic groups, and they are classified according to flagellar apparatus,

391 [1]Bacillariophyta, [2]Chloro phycophyta (green algae), [3]Chrysophycophyta (golden algae), [4]Cyanobacteria (blue green algae), [5]Phaeco phycophyta (brown algae), [6]Dinophyta (dinpflagellates), [7]Rhodo phycophyta (red algae)
Source: Oilgae,com. 2009.

cell division process, organelle structure and function which determine the oil yield respectively.

Table 7.4.3: Bioethanol Feedstocks with Repective Yield Capacity

Feedstocks	Yield (L/ha)	Average Yield (L/ha)	Usages
Miscanthus	7300	7300	Burning to generate energy, authentic paper making in Japan
Sugarcane	6800-8000	7400	Food, bioethanol, sweetener, alcohol (rum, cachaca)
Switchgrass	3100-7600	5350	Livestock feed, soil conservation to control erosion
Poplar	3700-6000	4850	Paper, inexpensive furniture,
Sorghum	2500-7000	4750	Syrup, cattle feed.
Corn	3100-4000	3550	Food, medicine, bioethanol, livestock feed

Source: Sanderson, K. 2006.

The table above justifies BP's/Shell's **the** NGB researches focusing much on the non-food biomass and energy grasses like miscanthus/switchgrass. Besides, both companies have also invested in sugarcane bioethanol through JV with Brazilian local companies[392]. Although sugarcane is a foodstock, due to the high economies of scale of Brazilian bioethanol, (while sugar production is also supported by other producing countries[393]), the food-fuel competition did not occurred on sugar. Hence, it is not the large scale of feedstocks, rather the efficiency (as natural characteristics of the feedstocks themselves), that would determine the large biofuels production output.

Appendix 7.5.1 the oil Companies' Diversified Strategies for the NGB Development

(a) JV

JV allows the combination of resources[394] to be shared between partners for the NGB R&D, the NGB production and penetration into foreign market for biofuels business expansion.

(i) Risks and costs sharing

Although JVs will divide the equities of the oil companies/partners hold, (consequently influencing their respective control authorities and entire profit possession), R&U could also be lowered to avoid severe financial/resources losses. Hence, there is a trade-off between high risk-high return, while JV provides shared risks with shared returns.

The R&D infrastructure and production plant are large and expensive. Rather than

392 In 2008, BP JV with Tropical Bioenergia to set up plantations and refineries producing bioethanol from Brazilian sugarcane. In 2010, Shell JV with Cosan to establish Brazilian sugarcane plantations and bioethanol processing facilities.

393 There are world top ten sugar producers: Brazil, EU, India, China, US, Mexico, South Africa, Australia, Thailand and Russia which could contribute to the food use on sugar. (Workman, 22 June 2007).

394 tangible resource such as land, capital, laboratories, machineries, infrastructure and intangible assets such as knowledge, skills and networking.

building their own facilities-which are not only costly[395], risky and time consuming, BP and Shell can access their partner's existing facilities, which could result in the commencement of the R&D, or the production of the NGB in a shorter timescale. The research points out that, BP and Shell have utilised their partners' existing research facilities/manufacturing plants, or are working together to construct some new production plants. There have been a few pilot demonstration plants set up by BP and Shell with their JV partners. These pilot plants could be turned into full scale commercial plants once the pilot testing on the production performance has been adequately accessed. The biotechnology/agriculture partners obviously have the absolute experiences, expertises and know-how for the most efficient/economic ways for the NGB development/production.

(iii) Building institutional knowledge for both parties
The biotechnology/agriculture partners are providing technical know-how of R&D and production capability; while BP and Shell are contributing their marketing experiences, supply/distribution infrastructure and their significant position within the regulated market[396]. From these JVs, the oil companies could gradually build up their institutional knowledge on the NGB R&D and production. Meanwhile, biotechnology/agriculture partners could learn from the oil companies at fuel marketing, distribution and supply know-how. Thus, the knowledge transfer mutually happens between them which result in the enriching of each parties institutional knowledge.

(iv) To obtain the NGB feedstocks and to penetrate new market
Through JVs with local partners, these help the oil companies to gain specific feedstocks required-which based on geographical factors; and help to ease the penetration into new marketplaces[397]. If any feedstock could be sourced from a country and produced in sufficient quantities, then biofuels could be supplied to this new market. This would allow a full exploitation of the supply chain, lowering the international trading costs and attaining economics of scale. The home-grown biofuels would not only capable of fulfiling the local demand and create job opportunities; but any surplus could also be exported to other parts of the world in order to create added value on biofuels produced.

(b) SA through joint R&D
SA is a contractual/agreement relationship between firms, in order to take advantage in sharing both firms' strengths[398], or to engage in activities such as R&D. SA is

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395 According to Dinneen (2007), the capital investment to build cellulosic ethanol facilities remains about five times than an existing corn ethanol plant, while the enzymes involved in the cellulosic ethanol process remain a significant cost as well.
396 Under the regulated market, oil companies have a closer relationship with regulators, and are constantly communicating with the policy makers for most of the decision on policy making relating to energy supply.
397 BP-India jatropha for Indian market, BP-British Sugar-Dupont use wheat for the UK market, BP-Tropical take sugarcane for Brazilian market, BP-Verenium utilise biomass for the US market. Shell-Iogen use wheat straw for Canadian market. Shell-Choren make use of biomass for German market. Shell-HRBP use algae for US market, Shell-Virent utilise energy grasses for the US market, Shell and Cosan make use of sugarcane for Brazilian market.
398 proprietary processes, intellectual, capital, market, distribution capabilities.

generally less cohesive than JV, and may often be designed to last for a limited time (Law, 2009). To date, BP has established two SA, while Shell has established one SA[399]. These SAs set up ways for the oil companies to work with biotechnology institutions in the NGB R&D, while not losing their individuality.

(c) Direct Funding

To date, BP has funded three projects while Shell has funded one[400]. These funded projects (exclude BP's EBI[401]) are complementing other ongoing the NGB R&D projects under the JV and SA collaborations, but signify a gap between BP/Shell (as projects funder) and executors whom are operating/conducting these projects. There are two conditions favouring this particular type of collaboration:

Firstly, through seeking new feedstocks and new process technology, these funded projects could open up more innovative findings, which can contribute to the knowledge pool and expand the potential feedstocks search (at different locations) and identify new efficient production methods, apart from what have been known so far from respective JVs and SAs collaborations. Secondly, due to the geographical distances which are beyond BP's/Shell's reach, funded projects could ensure the NGB development runs with minimal managerial involvement from the oil companies. BP's TERI jatropha project and Shell's six universities researches are located some distance from their own headquarters.

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399 BP established collaboration agreement with Mendel Biotechnology and joint development agreement with Martek. Shell joint R&D with Virent. The collaboration agreement formalises the relationships between the project participants and sets out the rights and obligations of each participant (Link Directorate, November 2000).

400 BP-TERI on Indian Jatropha, EBI, BP-Arizona State University for biodiesel, and Shell with six universities.

401 The EBI is BP's in house laboratory, set through pulling together three American universities for executing research operations. It is funded by BP, aimed for mid to long term establishment, with BP's participation for getting knowledge transfer from three American Universities. USD500 million has been injected for some ten-year research projects. Therefore it does not have gaps between funder and executor, since BP is participating in the NGB R&D projects.