9-10-2010

Adoption of Renewable Portfolio Standards in the United States: Which Factors Matter?

Angely Andrea Cárcamo Gallardo

Angely A. Cárcamo Gallardo
Candidate

Economics
Department

This thesis is approved, and it is acceptable in quality and form for publication:

Approved by the Thesis Committee:

Kristine Grimrud, Chairperson

Jennifer A. Thacher

Janie M. Chermak

Adoption of Renewable Portfolio Standards in the United States: Which Factors Matter?

by

Angely A. Cárcamo Gallardo

B.S. Electrical Engineering, Universidad de Concepción, Chile, 2005

THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of

Master of Arts
Economics

The University of New Mexico

Albuquerque, New Mexico

July, 2010

Dedication

To my parents, Rosa and René, and to my lovely husband, Jorge, for their support, encouragement and company throughout all those years in graduate school.

Acknowledgments

I would like to thank my advisor, Professor Kristine Grimsrud, for her support, guidance, advice, and cheering up conversations during my graduate studies, and especially during my thesis work. I would also like to thank the committee members, Janie M. Chermak and Jennifer A. Thacher, for their valuable time and recommendations about my thesis. Finally, to my parents, Rosa and René, and my husband, Jorge, for their unconditional and constant support and love; my friends and Rayitas, for being there when I needed support, to talk and have fun.

Adoption of Renewable Portfolio Standards in the United States: Which Factors Matter?

by

Angely A. Cárcamo Gallardo

ABSTRACT OF THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of

Master of Arts
Economics

The University of New Mexico

Albuquerque, New Mexico

July, 2010

Adoption of Renewable Portfolio Standards in the United States: Which Factors Matter?

by

Angely A. Cárcamo Gallardo

B.S. Electrical Engineering, Universidad de Concepción, Chile, 2005

M.A. Economics , University of New Mexico, 2010

Abstract

The Renewable Portfolio Standard (RPS) has become the most important instrument in United States to encourage the generation of electricity through the use of renewable energy. In brief, the RPS is a policy mechanism that requires suppliers of electricity to provide a specific percentage of their energy supply from some form of renewable energy. Such a percentage is referred to as the RPS ultimate target. In this thesis factors affecting the adoption of an RPS by U.S. states are investigated. Through statistical regression, this thesis specifically studies the effects of political views, energy endowments, electricity markets, economic factors, and other variables. These factors are related to pollution levels and geographical location in the adoption of an RPS and its ultimate target. Raw data from several federal agencies, national laboratories, and the U.S Census Bureau were collected and used in the analysis. Independent variables are related to energy generation, geographical location in the electricity generation grid, political tendency, economic indicators, electricity market, and pollution. The dependent variable represents the adoption or not of the RPS and its ultimate target. Since only a fraction of the states have adopted an RPS policy and defined a target, data associated with the RPS exhibits what is termed as a corner solution response, meaning that data is continuous and non-negative over strictly positive values, but takes the value zero for some non-trivial fraction of the population. Thus, a Tobit model was used for the analysis. Results indicate that the Tobit model yields a valid representation of the data. For comparison, a model based on an ordinary least squares (OLS) has also been estimated and its results are in agreement with those obtained for the Tobit model.

Contents

List of Tables

Acronyms

CO_2 carbon dioxide

NO_2 nitrogen dioxide

SO_2 sulphur dioxide

GHG green house gases

OLS ordinary least squares

DOE Department of Energy

EPA Environmental Protection Agency

PJM Pennsylvania New Jersey Maryland Interconnection

NERC North American Electricity Reliability Council

FERC Federal Energy Regulatory Commission

TRC Tradable Renewable Certificates

KWh kilowatt hour

MWh megawatts hour

MSW Municipal Solid Waste

NREL National Renewable Energy Laboratory

LBNL Ernest Orlando Lawrence Berkeley National Laboratory

MW megawatt

GDP Gross Domestic Product

EERE Energy Efficiency and Renewable Energy

AWEA American Wind Energy Association

GEA Geothermal Energy Association

DSIRE Database of State Incentives for Renewable Energy

LCV League of Conservation Voters

POU public owner utility enewable Energy Production Credit

PURPA Public Utility Regulatory Policy Act

PUHCA Public Utility Holding Company Act

RPS Renewable Portfolio Standard

U.S. United States

PUC Public Utility Commission

LSE Load-Serving Entity

IOU Investor-Owned Utilities

ESP Electric Service Provider

POU Publicly Owned Utilities

EIA Energy Information Administration

PTC Production Tax Credit

ESI Electricity Supply Industry

REC Renewable Energy Certificates

Chapter 1

Introduction

1.1 Introduction

In the 1970's, the stability of the U.S. energy supply became a national security concern because of the dependence on foreign sources of energy, especially oil. Since then, the dependence has increased. In 2007, the Energy Information Administration (EIA) estimated that approximately 58% of all the oil used in the U.S. is imported[1].

One of the world's most challenging problems is global warming. The major cause of this problem is emissions of green house gases (GHG) such as carbon dioxide (CO_2), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) into the atmosphere. These gases are mainly produced as a waste product when combusting fossil fuels. The generating sector of the power system is one of the major consumer of fossil fuels such as coal, oil, or gas and responsible for the 40.6 percent of all energy-related CO2 emissions[2].

[1] http://tonto.eia.doe.gov/energy_in_brief/foreign_oil_dependence.cfm (last acceseed 02/05/2009)

[2] ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/057308.pdf (last accessed 01/20/2009)

For both national security reasons and environmental concerns there is a movement towards generating a large portion of the electricity using renewable energy resources. Renewable resources are typically secure domestic resources and free of the most harmful GHG emissions.

Increased future demand for energy as a consequence of both economic and population growth, coupled with concerns about national security and the environment, has led to the creation of incentives for the use of renewable energy sources to generate electricity. These incentives include tax incentives, investment tax credits, Production Tax Credit (PTC), and regulatory mechanisms such as technology specification standards, target-based standards, and market facilitation or limitation policies.

Since the 1970's, concerns regarding the use of fossil fuels in energy production have increased, resulting in an interest in policies that can increase the amount of renewable energy sources in electricity generation.

The most popular policy tool to encourage the use of renewables in the electricity generation industry is the Renewable Portfolio Standard (RPS)[3]. In brief, the RPS is a policy mechanism that requires suppliers of electricity to provide a specific percentage of their energy supply from some form of renewable energy. Some of the RPS policies also permit the trading of Renewable Energy Certificates (REC). Since the first state enacted an RPS[4], the policy has become the most utilized policy to incentivize the use of renewables in electricity generation.

The government of President Barack Obama currently has plans to promote a healthy environment and energy independence in order to decrease the risk to national security and the economy. One of President Obama's proposals is to adopt

[3]The RPS is also termed as the Renewable Energy Standard, the Quota System, and the Renewable Obligation.

[4]Iowa in 1983

the RPS as a Federal policy (Obama). However, a Federal RPS would likely affect some states negatively, which may explain why some states have chosen not to adopt an RPS policy. States need to incentivize the use of renewables in the generation of electricity. RPS is one instrument to do so, with advantages and disadvantages. The advantages to a States from adopting and RPS include:

- a state can know and be ensured of the quantity of renewable energy being generated in the state,
- a state can lower the cost for achieving the RPS ultimate target by giving private market flexibility,
- an RPS is competitively neutral if it is applied to all load-serving entities,
- RPS has relatively low administrative costs and burdens, and can be applied in restructured and regulated markets.

Some disadvantages of an RPS are that:

- it is difficult to create a well designed RPS due to the complexity of the electricity market,
- it is less flexible than some other policy instruments that incentivize the use of renewables in electricity generation, in how it offers targeted support to some specific renewable energy sources or in how it is ensuring resource diversity,
- the cost impacts are not very well known in advance, and as a result states may have reduced control of the electricity price
- due to the fact that the operating experience emerging is new, there are many questions as to whether RPS policies will necessarily lead to long-term contracts.

A challenge for states willing to implement an RPS is rising electricity prices; therefore, most states allow the electricity supplier to comply with RPS goals by buying RECs. However, by using RECs, the emissions from electricity generation will not be reduced, causing localized pollution problems which, in turn, carry consequences for the environment.

A Federal RPS was proposed in 2002 and 2005 in both the House of Representatives and the Senate but was not approved. Separate Federal RPSs have been independently proposed by Senator Jeffords (a Republican senator of Vermont), Senator Bingaman (a Democratic senator of New Mexico), and Senator Coleman (a Republican senator of Minnesota). These Federal RPS proposals have some features in common: a renewable production target and schedule, a defined range of qualifying technology, tradable credits, and credit price caps with an exception for certain classes of retail electricity suppliers (Wiser et al., 2007).

However, there are also differences between the proposals. For example, in Coleman's proposal the qualifying technologies include nuclear power and fossil-fired plants that are required to capture and sequester carbon dioxide emissions. In the Bingaman proposal, which was passed to the Senate in 2002, and in a similar proposal in 2005, the existing hydropower would not count toward the clean energy requirement, but would reduce the retail supplier's renewable energy purchase obligation (Wiser et al., 2007).

All of the proposed Federal RPS policies include one important element in the RPS's design, namely, an accommodation of the pre-existing state's RPS policies. Bingaman's proposal specified that a "Federal RPS would not pre-empt state programs, and should coordinate to the extent practicable with such programs" (Wiser et al., 2007, pp. 18). However, this proposal did not address the decision of whether a certain type of generation complies with the federal target requirement or the financial compliance mechanisms, and penalties.

The main goal of this thesis is to determine and analyze the importance of all those variables, including technical, economic and political factors, that affect the likelihood of states adopting an RPS policy.

An important adverse factor for the states to consider is that adoption of an RPS policy by a state is associated with an incremental increase in the price of a kilowatt hour (KWh) (Chen et al., 2008). Due to the cost associated with investing in new technologies to generate electricity using renewables, the increment in the price plays as an important constraint for adopting the policy (Chen et al., 2008).

1.2 Background

During the latter part of the 19th century, starting with the creation of the light bulb in 1878 in Paris, electricity consumption grew very fast. The first public generation of energy was in Australia in 1895. In the early days of the Electricity Supply Industry (ESI) suppliers were public companies because the electricity was considered as a basic utility. For developing countries access to electrical power became a development indicator. As a consequence, developing countries, with the objective of expanding the electricity service to all customers and standardizing public services, started to nationalize their energy sectors in the 1940's.

Table 1.1: Types of Electricity Suppliers Considered in an RPS Policy

Term	Definition
Electric Utility	Either privately owned companies or public agencies engaged in the generation, transmission and/or distribution of electric power use. The electric utilities are regulated by state and Federal agencies.
Nonutilities	Generate power but do not own or operate transmission or distribution systems.
Load-Serving Entity (LSE)	Any supplier
Electric Service Provider (ESP)	Competitive entities
Federal Electric Utility	Include three operating entities that operate the Federal Hydroelectric plants. The entities are U.S. Army Corps of Engineers (Department of Defense), the Bureau of Indian Affairs (Department of the Interior), and the International Water and Boundary Commission (Department of State). The Federal Utilities Consumers are usually large industrial consumers or Federal Installations. Remaining energy is sold in the wholesale market to publicly owned utilities and rural cooperatives for resale at cost.

Table 1.1 – Continued on the next page

Table 1.1 – Continued from the previous page

Term	Definition
Publicly Owned Utilities (POU)	Are categorized as generators and non-generators. Generators are those electric utilities that own and operate sufficient generating capacity to supply some or all of their customers needs. However, some generators supplement their production by purchasing power. Non-generators rely exclusively on power purchases. Their primary function is to distribute electricity to their consumers. POUs include municipal authorities, state authorities, public power districts, irrigation districts, and other state organizations.
Rural Electric Utilities	Are formed and owned by groups of residents in rural areas to supply power to those areas. There are three types of cooperatives: (i) distribution only, (ii) distribution with power supply, and (iii) generation and transmission.
Investor-Owned Utilities (IOU)	Private and public supplier in the form of a holding company, in which a parent company is established to own one or more operating utility companies that are integrated with each other. IOUs sell power to different types of consumers and at wholesale rates to other utilities including other IOU public utility districts and rural electric cooperatives.

Table 1.2: Major Characteristics of U.S. Electric Utilities by Type of Ownership, 1998

Ownership	Major characteristics
Investor-Owner Utility (IOU): IOUs account for 75 percent of all utility generation and capacity. There are 239 IOUs in the U.S., and they operate in all States except Nebraska. They also referred to as privately owned utilities.	* Earn a return for investors; either distribute their profits to stockholders as dividends or reinvest the profits. * Are granted service monopolies in specified geographic areas. * Have an obligation to serve and to provide reliable electric power. * Are regulated by State and Federal governments, which in turn approve rates that allow operating companies to provide basic services for generation, transmission, and distribution.
Federally Owned Utility: There are nine Federally owned utilities in the U.S. and they operate in all regions except the Northeast, upper Midwest, and Hawaii.	* Power is not generated for profit. * Publicly owned utilities, cooperatives, and other nonprofits entities are given preference in purchasing from them. * Are primarily producers and wholesalers. * Producing agencies for some are the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, and the International Water and Boundary Commission.

Table 1.2 – Continued on the next page

Table 1.2 – Continued from the previous page

Ownership	**Major characteristics**
	* Electricity generated by these agencies is marketed by federal power marketing administrations in the U.S. DOE. * The Tennessee Valley Authority is the largest producer of electricity in this category and markets at both wholesale and retail levels.
Other Publicly Owned Utilities: Other publicly owned utilities include Municipally, Public Power Districts, State Authorities, Irrigation Districts, and other state organizations. There are 2,009 in the U.S.	* Are nonprofit state and local government agencies. * Service at cost; return excess funds to the consumers in the form of community contributions and reduced taxes. * Most municipalities just distribute power, although some large ones produce and transmit electricity; they are financed from municipal treasuries and revenue bonds. * Public power districts and projects are concentrated in five states, NE, WA, OR, AZ, and CA; voters in a public power district elect commissioners or directors to govern the district independent of any municipal government. * Irrigation districts may have still other forms of organization (e.g. in the Salt River Project Agricultural Improvement and Power District in AZ, voters for the Board of Directors are apportioned according to

Table 1.2 – Continued on the next page

Table 1.2 – Continued from the previous page

Ownership	Major characteristics
	the size of landholdings.) * State authorities, such as the NY Power Authority and the SC Public Service Authority, are agents of their respective state governments.
Cooperatively Owned Utilities: There are 912 cooperatively owned utilities in the U.S., and they operate in all States except Connecticut, Hawaii, Rhode Island, and the District of Columbia.	* Owned by members (rural farmers and communities) * Provide service mostly to members. * Incorporated under State law and directed by an elected board of directors which, in turn, selects a manager. * The Rural Utilities Service (formerly the Rural Electrification Administration) in the U.S. Department of Agriculture was established under the Rural Electrification Act of 1936 with the purpose of extending credits to co-ops to provide electric service to small rural communities (usually fewer than 1,500 consumers) and farms where it was relatively expensive to provide service.
Power Market: There are 194 active power marketers in the U.S.	* Some are utility-affiliated while others are independent. * Buy and sell electricity. * Do not own or operate generation, transmission, or distribution facilities.

Source: The Changing Structure of the Electric Power Industry 2000: An Update, October 2000, (EIA, 2000).

The organizational development of the ESI has been changing according to the technological capabilities, the sources of funding, and legislation related to organizational development. For the U.S., the development of the ESI has followed the same trends as the rest of the world. In the U.S., in the 1930's, the ESI was mainly composed of Investor-Owned Utilities (IOU) and the Public Utility Commission (PUC), both of which had a high degree of control regulating the utilities and their prices. However, by the 1930's three utilities controlled more than fifty percent of the generation of electricity in the U.S., and cost control was difficult to regulate, (Harris, 2006). In 1935, the states took control of the market power with two Acts, the Public Utility Holding Company Act (PUHCA) and the Federal Power Act. The PUHCA forced large utilities to break into vertically integrated utilities, and the Federal Power Commission[5] was given the authority to grant licenses for generation and transmission, giving control to the companies and assuring fair and non-discriminatory access (Harris, 2006).

In addition, regional cooperation between energy transmission areas started in 1927 with three utilities, creating the first power pool. In 1957 those utilities became the Pennsylvania New Jersey Maryland Interconnection (PJM) with the joining of two other utilities. The lack of self regulation of the electricity market produced an increased need for technical management. This insufficiency in regulation triggered the creation of the North American Electricity Reliability Council (NERC) in the late 1960's. The NERC is the entity in charge of ensuring the reliability in the bulk power system in United States (U.S.).

[5]The Federal Electricity Commission in 1978

1.2.1 Electricity Market and Deregulation

In the 1970's, after the first oil shock, the stability of the U.S. energy supply became a national security concern because of the dependence on foreign sources of energy, especially oil. In 1973, President Nixon "launched Project Independence with a legal deterrent to generation from imported fossil fuel in the form of oil and natural gas" (Harris, 2006, pp. 18). This project was the starting point for a series of policies and mechanisms looking for new sources of energy, with the main goal was to make the U.S. independent of foreign sources of energy.

In 1978, under President Carter's administration, the Public Utility Regulatory Policy Act (PURPA) was passed. PURPA forced participants in the electricity market to accept power generation from qualifying facilities in order to reduce costs. Specifically, the PURPA required utilities to purchase renewables and others independent electricity at prices that reflected the long run cost of new, high-cost nuclear and fossil fuel plants (Jaccard, 2004). Before PURPA, only utilities could own and operate electric generating plants. PURPA required utilities to buy power from independent companies that could produce power with lower costs than those incurred by the power utility generation; this was termed as the "avoided cost."

In the U.S. in the 1980's, the organizational development objective was to reduce the costs to customers and increase innovation through competition. Currently, the ESI companies are primarily influenced by their ownership and finance. There are five different categories of electricity suppliers classified by ownership: investor owned corporation, public sector (towns, municipalities, public corporation, federal agencies), cooperatives (in practice a very small percentage), individual or privately owned companies (Harris, 2006). Table 1.1 summarizes some of the terminology used in the explanation of the RPS. In addition, Table 1.2 explains the major characteristics of U.S. electric utilities by type of ownership (EIA, 2000).

In 1992, the Energy Policy Act allowed independent generators to sell their power directly to the local distribution network and supply companies, even if this meant selling the power to other power generators. Also, the Energy Policy Act gave the right to provide transportation without discrimination. It must be commented that at the beginning of the ESI, generators owned the transmission lines. They had the right to allow or deny access to their transmission lines for other generators not following the regulation for selling the energy produced. Since 1996 with the Federal Energy Regulatory Commission (FERC) Orders 888 and 889 transmission[6] was defined in a wide sense: making the transmission lines available to be accessed by any supplier, specifying a safety factor for the maximum load in the transmission lines, and establishing that generators must balance the supply of energy among their customers.

In summary, it can be seen that the variety of the structural forms of ownership operation and control of the power grid in the U.S. is the consequence of the technical, physical and socioeconomic complexity of the industry.

Since 1978, the U.S. Government has created incentives for the use of renewable energy sources to generate electricity. These incentives include tax incentives, investment tax credits, Production Tax Credits PTC, and regulatory mechanisms such as technology specification standards, target-based standards and market facilitation or limitation policies (Kreith and Goswami, 2007). One of these incentive mechanism is the RPS. To date, the RPS is the most exercised industry-incentive mechanism for the use of renewable energy in electricity generation in the U.S. Since the 1990s, the RPS has been adopted by 25 states and the District of Columbia. Half of the 26 programs in existence at the end of 2007 were created in 2004 (Wiser and Barbose, 2008).

[6]http://www.ferc.gov/legal/majordreg/landdocs/rm95900k.txt (last accessed 05/15/2010)

Chapter 2

Renewable Portfolio Standard Policies

2.1 Policy Description

Since the late 1990s, RPS policies have been implemented increasingly across states and have emerged as an important driver for renewable energy capacity additions in the U.S. (Wiser et al., 2007). Initially, the RPS was proposed as a mechanism to support renewable energy development in competitively restructured electricity markets. Now, the RPS has become a policy that encourages fuel diversity in the electricity market (Cory and Swezey, 2007).

The RPS policies are designed to maintain, increase, or significantly increase the use of renewable energy in the electricity supply. An RPS establishes a specific quantity or percentage as a renewable energy supply target for retail electricity suppliers[1]. In addition, RPS policies intend to encourage competition between renewable developers to reach the target level at the minimum possible cost.

[1] This target is also known as "renewables obligation" or "quota system."

The RPS has two major definitions[2]:

Definition 1. The Renewable Use Portfolio Standard is an approach that requires the use of renewable energy. The electricity supplier can choose to generate its own renewable energy or purchase it from other electricity suppliers.

Definition 2. The Renewable Production Portfolio Standard is an approach that forces the electricity supplier to produce a specific amount of its electricity using renewable resources. This approach does not allow the suppliers to buy credits or seek out other less expensive alternatives to achieve the policy goals (Wiser et al., 2005).

The definition of RPS used in the U.S. is a mix between definition 1 and 2. *A mechanism with the objective of increasing the supply of electricity generated using renewable energy. Such an objective is achieved by either requiring or forcing electricity suppliers to generate or purchase renewable energy from other suppliers.*

In the U.S., an RPS policy is fundamental for the future of the electricity market because it encourages investment in renewable energy generation capacity and is used as a mechanism to decrease emissions produced from electricity generation. Renewable sources for RPS are sunlight, heat, geothermal, wind, wave power, tidal energy, organic matters, and small hydropower (less than 20 MW) (Rabe, 2006; Wiser and Barbose, 2008).

The design of RPS policies vary across states, however, the definition has a common objective: it requires a Load-Serving Entity (LSE) to comply with a specific minimum quantity of suitable renewable energy (Wiser and Barbose, 2008). As a part of its design, an RPS policy defines a numeric target for renewable energy supply; that is, it requires electricity suppliers or LSEs to include a specific amount or

[2]In the U.S. there is no difference between Definition 1 and 2 because compliance mechanisms differ across the states.

percentage of renewable energy as part of their supply portfolio, thereby increasing the production of electricity from renewable energy sources and simultaneously, encouraging competition among renewable development to reach new targets in a least-cost fashion (Wiser and Barbose, 2008). The RPS establishes specific numeric targets, which are designed to increase over time. This is done to further encourage competition among electricity suppliers, and to create and give incentives to industry to accelerate the development of new renewable technologies at reduced production costs.

The RPS is a market friendly incentive to achieve the minimum amount of clean energy required by each state's government. The RPS has become the most used policy renewable incentive to increase energy production because it does not necessarily require an explicit allocation of governmental funding.

Under the RPS policy regime, electricity suppliers have three ways to achieve the goal or percentage of supplied electricity produced using renewable energy by:

1. producing more renewable energy itself
2. purchasing renewable energy produced by other supplier
3. buying Renewable Energy Certificates (REC)[3].

Different ways to comply with the policy across states is one of the major problems for the adoption of a national RPS proposal.

The RPS requirements that apply to retail electricity suppliers have some flexibility in the way the company can acquire the renewable generation. RECs are

[3]RECs are also termed Renewable Energy Certificate, Tradable Renewable Certificates (TRC), Renewables Energy Attributes, or Green Tag. REC corresponds to the attributes of one megawatt-hour megawatts hour (MWh) generated using renewable energy. RECs are a financial product, market instrument or tradable commodity separated from the physical electricity generated created "by separating the attributes of renewable electricity generation from physical electricity produced" (Cory and Swezey, 2007, pp. 22).

useful to retail suppliers because they have the option of demonstrating compliance with the RPS by buying RECs, in lieu of directly producing "watts of renewable electricity." Thus, RECs play an important role in helping the utilities comply with the policy target when the policy allows the companies to trade them. Across the U.S. many RPS policies use tradable RECs to increase flexibility, to reduce the cost of compliance, and to track compliance more easily. REC trading, banking, and borrowing are allowed in most states. RECs are usually purchased using long-term and short-term contracts or spot purchases. In addition, the renewable generators have another revenue stream with REC transactions.

The RPS design characteristics also vary across the states in design, target selection, incentives to develop expensive technologies such solar and photovoltaic, social benefits, etc. However, for the purpose of this thesis, an RPS with a policy requiring electricity generators to supply a specific quantity of renewable energy has been assumed. The theory and conceptual design of RPS sounds simple and straightforward; however, in practice its design and implementation vary in important ways from one state to another making analysis challenging. The major types of policy variation were categorized by the Ernest Orlando Lawrence Berkeley National Laboratory (LBNL), and can be seen in Table 2.1 (Wiser et al., 2005).

Table 2.1: RPS Policy Design Options

Structure, Size and Application	**Eligibility**	**Administration**
- Basics energy vs. capacity obligation	- Geographic eligibility	- Regulatory oversight body(ies)
- Purchase obligation over time	- Resource eligibility	- Verify compliance-RECs or contracts-path
- Structure single tier or multiple tiers	- Eligibility of existing renewable generation	- Certification of eligible generators
- Resource diversity requirements or incentives	- Definition of new incremental generation	- Compliance filing requirements
- Start date	- Treatment of multi-fuel facilities	- Enforcement mechanisms (penalties)
- Duration of obligation (sunset provisions)	- Treatment of off-grid and customers-sited facilities	- Existence of cost caps and alternative compliance payments
- Application to retail suppliers, and exemptions from obligation		- Compliance flexibility mechanisms (banking, borrowing, etc)
- Product or company-based application		- Contracting standards for regulated Retails suppliers, LSEs
		- Cost recovery for regulated retail suppliers
		- Interactions with other energy and environmental policies

Source: Lawrence Berkeley National Laboratory

The RPS design varies across the U.S., Table 2.1 summarizes the main sources of variation. The design features can be classified into the following groups: target selection, eligibility of resources, applicability. flexibility mechanisms, and administrative responsibilities. It must be noted these features are all interconnected. Also, the RPS group of standard policy objectives plays an important role in the design. These RPS objectives are the following: effectiveness, equity, political acceptability, administrative feasibility, and the specific environmental and social motivation for the RPS (Jaccard, 2004). In particular, the major design features are:

- *Target selection*[4] is the selection of the portion of renewables in the energy mix in the ultimate target size, target timing, whether there is one or multiple renewables targets, target adjustment and other cost cap measures.

- *Eligibility of resources*[5] includes renewables versus other desired technologies (e.g. biodiesel, tidal current, fuel cells using renewables fuels, and digester gas), existing renewables versus new investments, grid-connected renewables versus all renewables, facility size, and import versus exports.

- *Applicability* includes geographic coverage, the types of market participants regulated by the RPS, and whether energy production or installed capacity is considered.

- *Flexibility mechanisms*[6] include account-balancing mechanisms for individual producers, and trading mechanisms between producers.

[4]Target selection may have an impact on costs depending on local costs, availability of renewables, and the price of conventional electricity.

[5]The eligibility of resources depends on the RPS objective and the resource location viability.

[6]The RPS can be less costly to implement depending on how flexible the RPS is when applied to the producers, individually and across the market.

- *Administrative responsibilities*[7] include the responsibilities in the implementation such as setting the RPS target, certification of renewables, compliance monitoring, and setting and collecting penalties for noncompliance.

The success of the design of an RPS policy for a state depends on whether it is sufficiently balancing conflicting policy goals. There are several policy principles and best practices which can guide policy makers when they face up policy tradeoffs. The policy principles used in the design of RPS policies are the following (Wiser et al., 2005):

- *Social benefits:* the policy will incentivize an increased renewable energy production, thereby contributing to the environmental quality and increasing the diversity of energy supply among other political chosen objectives.
- *Cost effectiveness and flexibility:* both the implementation and the administration have to be straightforward, flexible, cost effective, and not too demanding.
- *Predictability:* the policy should provide stable market for all the participants, while reducing regulatory risk and improving the ability to develop long-term contracts with the consumers.
- *Nondiscriminatory:* the policy should be applied to all the participants in the market, that is, all the utilities and all the consumers, if required.
- *Enforceability:* the policy should have some way to enforce that all market participants comply with the target and major goals.
- *Consistency with market structure:* the policy should be designed according to the type of market present in the state regardless of whether it is regulated or not. For example, in a competitive market the policy should be applied

[7]These responsibilities in the implementation of RPS can be handled by a single administrator or by specialized agencies.

to all the participants in order to avoid the creation of an artificial barrier to competitive entry. In the case of a vertically integrated market, the policy has to establish clear contracting standards to ensure long-term contracts for the renewable generators, thereby ensuring prudent compliance practices. Also in competitive markets the policy has to ensure cost recovery in the electricity rates.

- *Compatibility with other existing policies:* the RPS policy must be compatible with other policies and regulations already adopted by the state or federally. For example, the policy must be in agreement with the charge system of benefits[8] and the tax incentives that are designed to encourage the investment in renewables. If the RPS is to be applied to a market where emission rights are present, policy-makers must ensure that these rights stay bundled with RECs from the RPS.

Due to both inherent differences among states as well as differences in the progress made in implementation of policies, the RPS has to be analyzed following specific criteria (Wiser et al., 2005):

- *Outcome criteria:* refers to the value of the actual impact and results of state RPS policies such as renewable energy development, economic costs, and other outcome-based criteria.

- *Policy design criteria:* covers the legislative and regulatory RPS design features that may affect on the success of the RPS.

- *Market context criteria:* takes into consideration that even a well-design RPS can fail in yielding an effect on the market.

[8]small charge on customers' electricity rates

The RPS numeric targets typically increase over time and retail suppliers must demonstrate compliance with the RPS's target annually. Often, the suppliers suffer penalties if they do not achieve compliance.

The most common target policies specify a periodic schedule, typically annual, that specifies the share amount of electricity sales that must be accounted for in order to comply with RPS. In certain instances, targets are based on absolute generation or installed capacity.

Although the term "renewable" is commonly used in the design of the RPS, there is no official agreement about eligible resources. Typically, when wind, solar, geothermal, landfill–gas, and ocean-based energy resources are available in the state, these resources are accepted for compliance with the RPS requirement. On the other hand, biomass, Municipal Solid Waste (MSW) incineration, and hydropower resources greater than 20 MW are not frequently used to comply with RPS requirement. The inclusion of hydropower as part of the RPS must be submitted for approval to policy-makers depending on its size, age, or design, such as the run-of-river and storage projects. Some projects allow other options to comply with the final target, including allowing non renewable generation or non-generation activities, such as energy efficiency programs that help the retail suppliers to earn credits towards reaching the target. All the aforementioned options to meet the target may vary according to the geographic location of the eligible generators and the specific requirement of generators to locally deliver the electricity.

The RPS policy costs are expected to be recovered by the utilities. Regulated utilities recover their cost-of-service through a standard rate-making proceeding. When retail competition is allowed, cost recovery is not certain. However, any excess cost is likely to be passed on to the electricity consumers, and in some states, the government will absorb some of the costs. The government uses cost caps to determine the cost limits of the RPS compliance. Moreover, several mechanisms to enforce

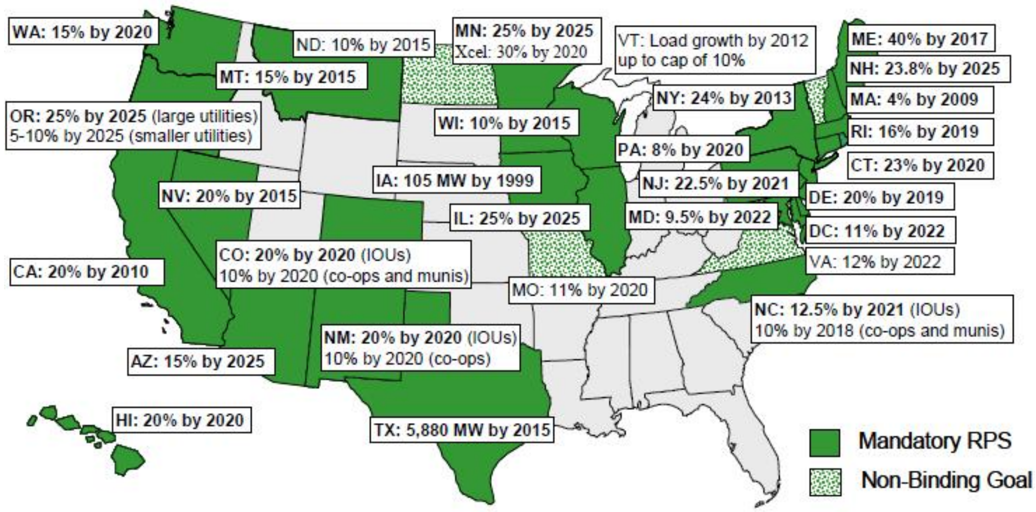

Figure 2.1: Definitions of RPS Policy Across the States. (Source: RPS in the United States: A Status Report with Data Through 2007, Wiser and Barbose, 2008. LBNL.)

the RPS are used, including electricity license revocation and civil fines. Alternative ways to comply with the RPS without renewable generation are statutory waivers and discretionary waivers.

RPS policy varies widely from one state to another. For example, an RPS varies in the target selection and the year of compliance. This can be from 4% in MA for 2009 to 40% in ME in 2017. Also, in AZ, WA, CA, TX, NM, CO, MA, NC it is mandatory to comply with the target. While in MN it is not. Figure 2.1 shows the variations in ultimate RPS target.

Moreover, the differences are not only in design. The RPS has been enacted very differently across the states. For example, in Arizona and New York RPSs were enacted using the regulatory channel, while in Colorado and Washington they were enacted through voter-approved initiatives. In some states the target required by the RPS is mandatory and in others the target is voluntary [9]. Currently 25 states and the District of Columbia have adopted the policy with mandatory obligations in restructured electricity markets and in cost-of-service regulated markets, covering approximately 40% of the total electrical load.

2.2 Literature Review

By the year 2007, a RPS was effectively implemented in 25 states and the District of Columbia with targets for the renewable energy requirement, ranging from 2% in Iowa to 40% in Maine. Other states, such as Illinois, Vermont and Virginia, have established non-binding renewable energy goals. The RPS has different time horizons among the states in order to achieve the quota selected. Also, there are differences in the design, which include technology and geographic eligibility, methods used to reach the compliance, and specific implementation. These differences create challenges in forming conclusions about the effect and applicability of the RPS throughout the entire nation (Cory and Swezey, 2007).

The National Renewable Energy Laboratory (NREL) and the LBNL have conducted several studies regarding different aspects of the RPS policy. Some of these studies evaluate U.S. experiences with RPS, study the RPS goal and implementations strategies applied so far in U.S. (Wiser et al., 2007), (Cory and Swezey, 2007). Advantages and disadvantages of the RPS performance relative to other renewable energy policies have also been reported in the literature. Wiser *et al.* (2004) concluded that the experience from the U.S. has shown that a well-designed and well implemented RPS policy is effective policy in supporting incremental use of renewable energy (Wiser, 2004). Examples of a well-performing RPS policies are found in Texas, Iowa, and Minnesota. Texas has been successful in increasing the new

[9] The target quota is voluntary in Iowa, Illinois, Vermont, and Maine.

renewable load capacity at a reasonable cost (Langniss and Wiser, 2003). Iowa and Minnesota are currently achieving successful results in their energy requirements, achieving their goals of renewable energy purchase by the IOU and the larger state utility, respectively (Wiser, 2004). In other states, the RPS has not been in use for a sufficient time to evaluate results. From all the experiences in the application of the RPS, some typical design failures faced by the states can be summarized. These failures are: "narrow applicability, poorly balanced supply-demand conditions, insufficient duration and stability of targets, insufficient enforcement, and poorly defined or non-existent contracting standards and cost recovery mechanisms for regulated utilities and providers of last resort," (Wiser et al., 2005, pp. 261). In a market context, criteria of a well-designed RPS policy usually includes "credit-worthy long-term power purchasers, stable political and regulatory support, and adequate and accessible renewable resource potential," (Wiser et al., 2005, pp. 261).

In 2006, the Environmental Protection Agency (EPA) described the most important features of an RPS policy. The work states that these features include applicability to the market participants, resources eligibility, policy administration, cost caps, and cost recovery. The RPS policy implementation issues can be divided in resource availability, resource-specific provisions, political and regulatory consistency, and ability to finance new projects (Environmental Protection Agency, 2006).

Renewable resources available in each state vary across the regional climates and geographies. The renewable energy resources such as biomass, solar, photovoltaic, wind, geothermal, natural gas, and coal can be seen in the Figures 2.2 to 2.8. The natural resources distribution is not equitable across the states for example the south-west is rich in solar reserves but it is not in biomass nor wind.

An important RPS objective is to encourage competition between renewable electricity suppliers. Challenges of many renewable energy technologies are costs, measurement and verification issues. A good example is solar energy which has a problem

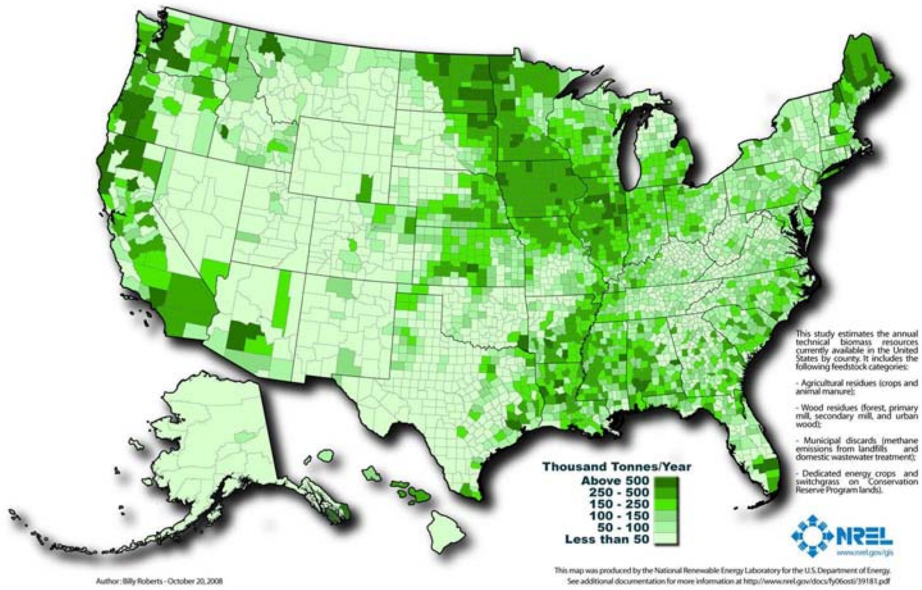

Figure 2.2: Distribution of Biomass in USA. (Source: NREL)

for compliance the RPS goals due to its output measurement and verification. Some states to encourage the use of solar energy giving some incentives to its consumers helping the competition between renewable electricity suppliers.

Political and regulatory consistency are important for market confidence. If these features are not appropriately established, they can create uncertainty about the stability and longevity of the law, decreasing investor confidence. Negative factors in this aspect include compliance waivers, vague eligibility definitions, low costs impact thresholds, and weak enforcement penalties.

It is important to note that an RPS must create and manage conditions allowing new electrical projects to be financed and built. The market structure can be regulated with a single supplier or restructured from market competition. In either case, it is essential to have a creditworthy purchasing entity.

In summary, there are a large and diverse number of issues associated with the

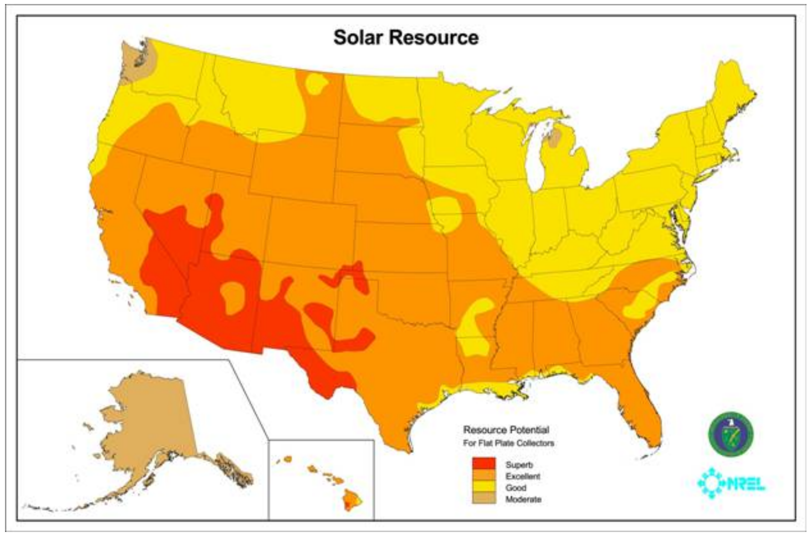

Figure 2.3: Distribution of Solar Resources in USA. (Source: NREL)

design of an RPS across the states. However, it is believed that a federal RPS could

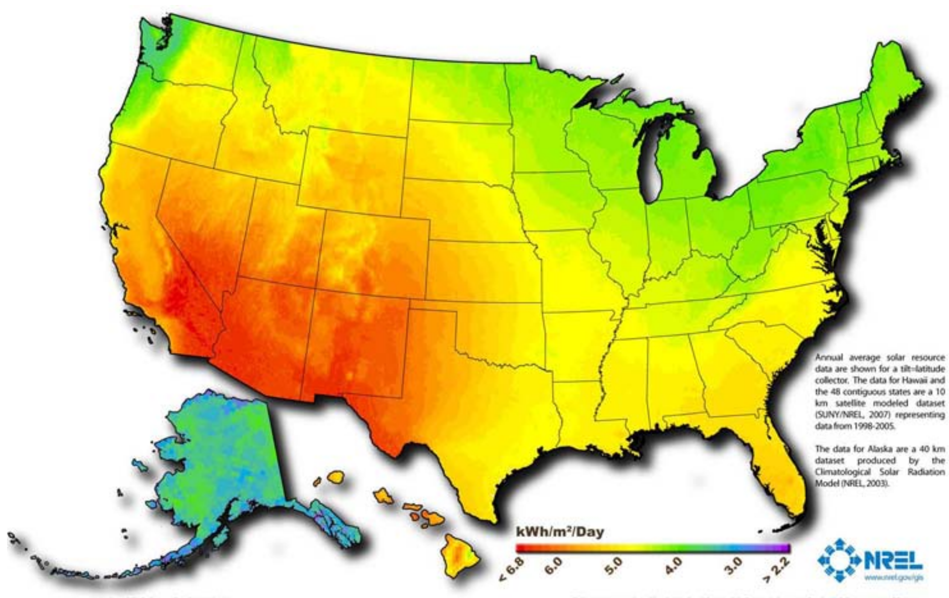

Figure 2.4: Distribution of Photovoltaic Solar Reserves in USA. (Source: NREL)

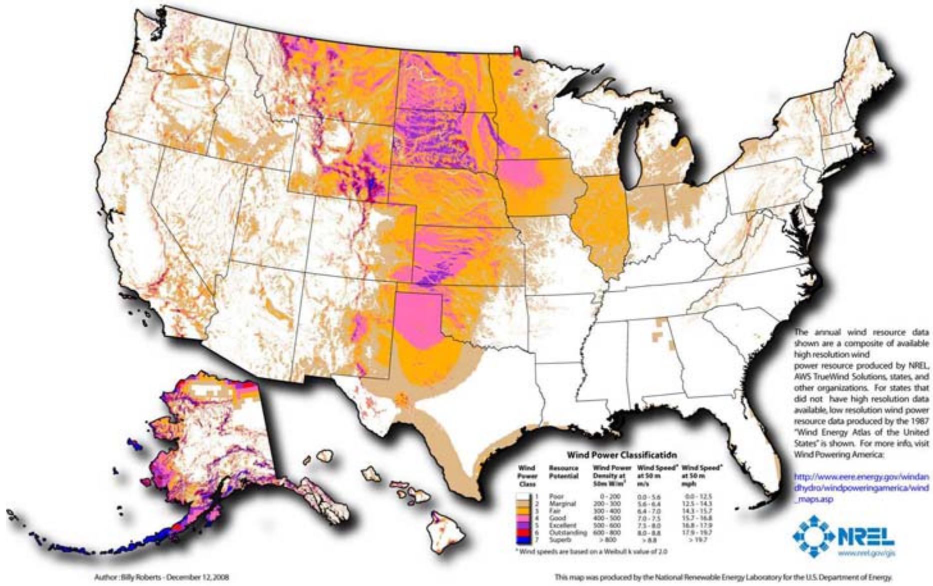

Figure 2.5: Distribution of Wind in USA. (Source: NREL)

provide a solution to those problems (Sovacool, 2008). A national RPS should be designed to reduce market distortions, to bring uniformity and predictability into

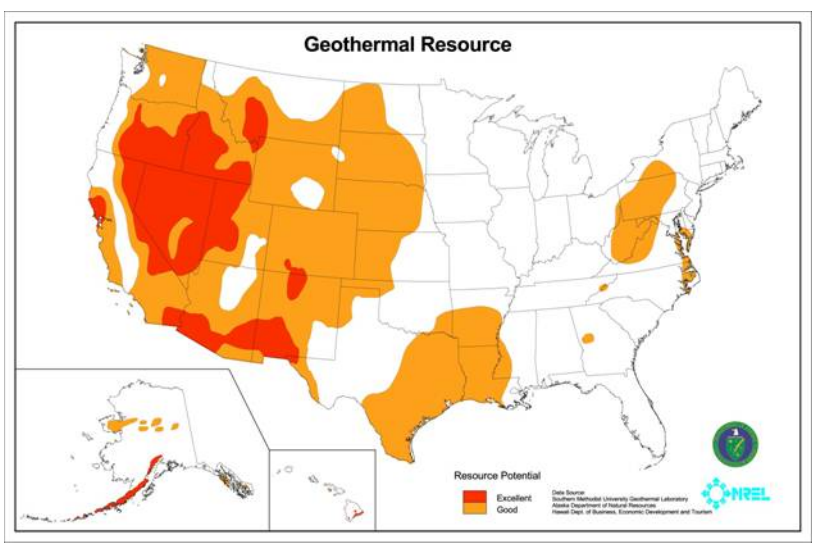

Figure 2.6: Distribution of Geothermal Resources in USA. (Source: NREL)

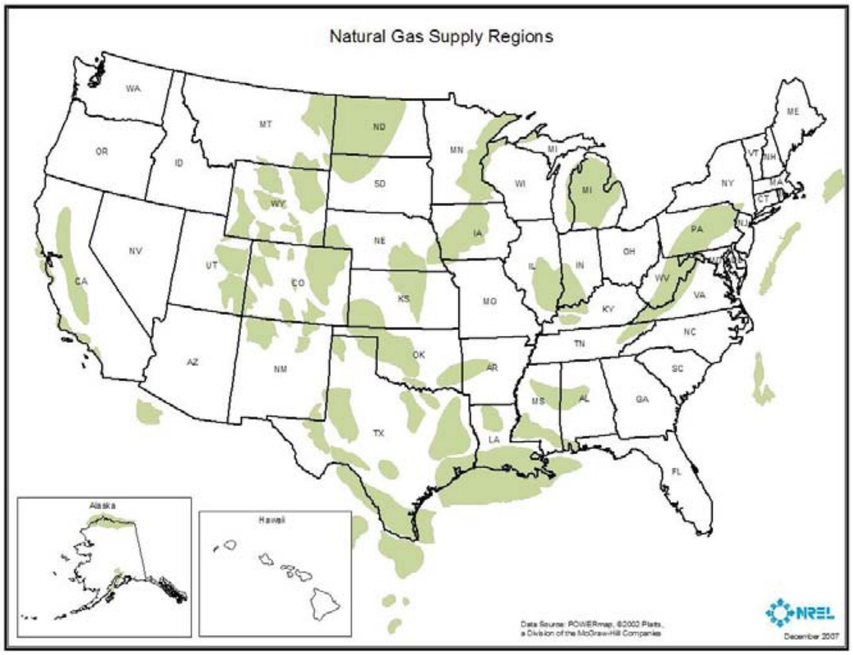

Figure 2.7: Distribution of Natural Gas Supply in USA. (Source: NREL)

the renewable energy market, and to promote diversity of the nation's electricity fuel mix. Also, "a national RPS would diminish conflict over RPS eligible fuels, reduce uncertainty over the duration of state RPS policy and eliminate inequities created by "free rider" states that enjoy artificially low prices while others states pay to clean up the effects of cheap, dirty fuels" (Cooper, 2008, pp. 10). Moreover, several authors outside national laboratories have been studying RPS as an instrument to incentivize the use of renewables in electricity generation in different contexts.

Palmer and Burtraw (2005), found that the increased price in states that adopted an RPS would result in reduced the natural gas generation rather than reduced coal production. The authors analyzed the effects of two government policies which are designed to increase the supply of renewables in U.S., RPS and Renewable Energy

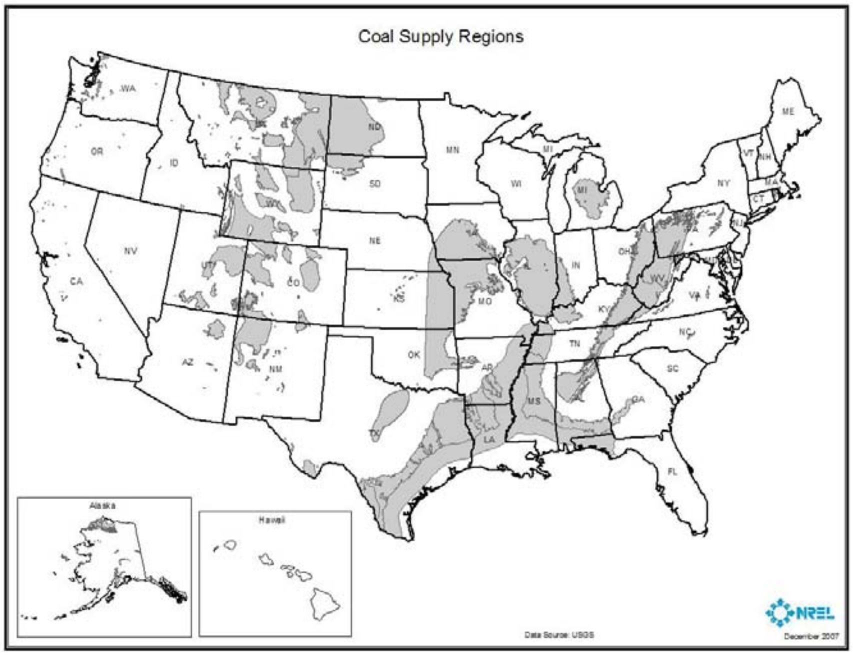

Figure 2.8: Distribution of Coal Reserves in USA. (Source: NREL)

Production Credit (REPC)[10]. The authors simulate the effects of both policies in the electricity market considering the effects of costs, utility investment, technologies and fuels used to generate electricity. They analyzed the effects on electricity prices and on carbon emissions from electricity generators. Palmer and Burtraw (2005) concluded that "RPS is more cost-effective then REPC, both as a means of increasing renewables and reducing carbon emissions"(Palmer and Burtraw, 2005, pp. 874). Also they find that the production of natural gas will decrease in states which did not adopt carbon taxes or cap and trade policies.

Knittel (2006) analyzed the role of interest groups in the adoption of an RPS in the states. The author models states' decision to adopt an RPS policy as a hazard rate. The author concludes that the adoption is positively correlated to the capacity

[10]REPC are tax credits for certain types of renewables.

of shortages, high level of wealth, and lower residential electricity penetration rates[11] (Knittel, 2006).

Huang *et al.* (2007) investigated the influence of the factors involved in the decision of adopting an RPS by the states in the U.S. The authors employ economic, environmental, and political explanatory variables in a cross sectional data analysis. However, the analysis cannot control for the effect in some explanatory variables across the time. For example, the author cannot analyze the effect of some variables such as date of adoption of an RPS or in reductions of pollutants across time. In this paper, the authors consider socioeconomic, political, and environmental factors which impact on the adoption of an RPS by a state. Huang *et al.* conclude that high educational levels in a state and high gross state products are factors with a greater effect on the increment in the probability to adopt RPS among other socioeconomic variables. Huang *et al.* analyzed the influence of some factors, such as socioeconomic, political, and environmental, on the adoption of an RPS by state. The authors observed that the gross state product, the growth rate of population, the level of education, and the share of coal in electricity generation have a positive effect on the adoption of an RPS by a state. In addition, they observed that the expenditure on natural resources and the political party dominance have a negative influence on the adoption of an RPS by a state. It must be noted that the authors acknowledges some important limitations in his study. In particular, he observes that the lack of data about the distribution of natural resources expenditure affects the representability of the model. In addition, since the work is not a panel data analysis, Huang et. al are not able to account for the time evolution of the variables considered (Huang et al., 2007).

Lyon and Yin (2008) conducted a study similar to Huang *et al.* (2007) but

[11] A penetration rate, defined as the number of active electricity customers within a specific population, provides an indicator of whether residential customers are receiving electricity services or not.

solving Huang's timing problem using a panel data analysis. By collecting historical data they analyzed empirically the political and economic factors that induce the state Government's decision to adopt an RPS. Lyon and Yin observed that states with high wind potential, high amounts of air pollution, and a majority presence of democrats in state legislature is more likely to adopt an RPS. Also, the authors observed that economic benefits are not important factors for legislators on whether to adopt or not an RPS (Lyon and Yin, 2008).

Moreover, Li *et.al* (2008) investigated how much U.S. households are willing to pay to support increased energy research and development activities with the objective of replacing fossil fuels. The authors collected data from a mixed mode telephone and internet survey. Using a contingent valuation they estimated the annual households willingness to pay for national energy research. The authors observed that perceptions of the "importance of energy issues, the need to reduce dependence on foreign energy sources, and the benefits of development of crop-based fuels significantly and positively influence respondents' support for the creation of a national Energy Research and Development Fund" (Li et al., 2008, pp. 11).

To the best of my knowledge, Huang *et. al* (2007) is the most similar work to this thesis.

Chapter 3

Analysis

3.1 Hypothesis

This Master's thesis investigates factors that affect the adoption of the Renewable Portfolio Standards by individual states. Using a regression model, this thesis specifically studies the role of political views, energy endowment, electricity market, economic factors, and other variables related to pollution and geographical location, in the adoption of the RPS and its ultimate target.

This work does not follow any specific work available in the literature; however, it examines several similar aspects of the work presented by Huang *et al.* (2007). Since both analysis employ cross sectional data, the results obtained for some variables can be compared.

The data used in this work is selected following the general definition of RPS and policy goal (Rader and Hempling, 2001). The data is divided into several categories including RPS features, energy generation variables, geographical variables, political variables, economic variables, electricity market variables, and pollution variables.

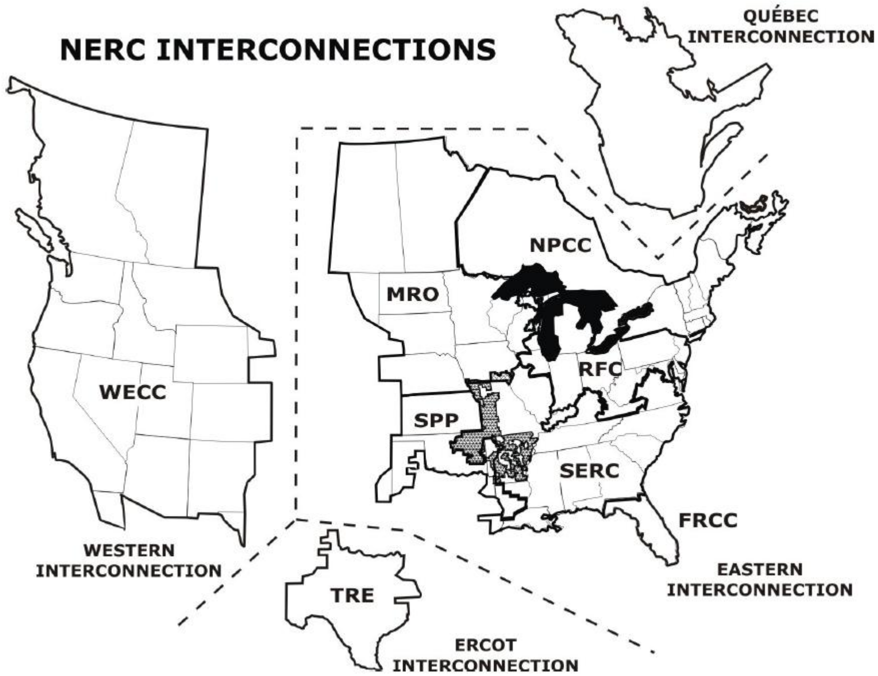

Figure 3.1: NERC Interconnection Map. (Source: http://www.nerc.com, last accessed 12/01/2009.)

3.2 Data

The original data are collected from federal agencies, national laboratories and the U.S. Census Bureau. The specific data sources include EIA, NREL, LBNL, Database of State Incentives for Renewable Energy (DSIRE), Energy Efficiency and Renewable Energy (EERE), and the U.S. Census Bureau. For each state, all variables exhibiting some direct or indirect relationship with the adoption of an RPS policy and/or its specific goals, were carefully selected from the aforementioned data sources. It must be mentioned that since some states already have adopted an RPS policy, the presence or absence of RPS is coded here as a dummy variable. All the data collected for this work are from 2006, which corresponds to the latest available information released by EIA at the time this research was conducted.

Table 3.1: Data Description and Value Encoding

Name	Description, Value Encoding & Units
rps!	Dummy variable. If RPS is enacted in state then rps=1, otherwise rps=0
represen	Total number of representatives by state in the congress.
govd	Dummy variable. If the state has a democratic Governor the variable equal 1, otherwise is 0
henvscore	Percentage of pro-environmental laws voted for each representative in 2006
east	Dummy variable. If the state is located in the East region the variable is 1, otherwise is 0
msw[1]	Energy produced from Biomass-Waste-Landfill Gas, MSW (Municipal Solid Waste) Variable units is thousands of KWh
otherbio	Biomass-Waste-Other. Biomass power generation. Variable unit is thousands of KWh
wood	Wood and derived fuels power generation. Variable unit is thousands of KWh
geo	Total geothermal power generation in the state. Variable unit is thousands of KWh
hydro	Total hydroelectric power generation by conventional technology. Variable unit is thousands of KWh
solarpv	Total Solar and Photovoltaic power generation in the state. Variable unit is thousands of KWh
wind	Total wind power generation in state. Variable unit is thousands of KWh
netgen[2]	Net power generation in the state. Variable unit is thousands of MWh

Table 3.1 – Continued on the next page

[1]EIA-Table 1.18 Renewable Electric Power Sector Net Generation By Energy Source and State, 2006 (1000 of KWh)
[2]EIA-Table A.1S elected Electric Industry Summary. Summary Statistic by State 2006 (MWh)

Table 3.1 – Continued from the previous page

Name	**Description, Value Encoding & Units**
trenetgen	Total Renewable Net power generation. Variable unit is thousands of MWh
totreinst	Total renewable power generation installed in the state. Variable unit is thousands of MWh
perfossil	Percentage of electricity generated using fossil fuels by state.
perhydro	Percentage of electricity generated using hydropower generation by state.
perwind	Percentage of electricity generated using wind by state. Variable in %.
co2[3]	Amount of CO_2 emissions produced by electricity generation in state. Variable unit is thousand metric tons.
no2	Amount of NO_2 emissions produced by electricity generation in state. Variable unit is thousand metric tons.
so2	Amount of SO_2 emission produced by electricity generation in state. Variable unit is thousand metric tons.
price	Average price of a KWh in the state. Variable unit is cents of dollars per KWh.
Incpercap[4]	Average household income per capita by state. Variable units is U.S. dollars
Population	Total population by state. Variable unit is number of habitants.
gdp[5]	GDP in the state. Variable units is millions of U.S. dollars

[3] EIA.Emissions by states 2006 in thousand metric tons

[4] U.S. Census Bureau by state 2006

[5] The data source for Gross Domestic Product (GDP) was Table 5 of the U.S. Census Bureau of Economic: 'Analysis in Current-Dollar GDP by State, 2004-2007, Millions of dollars.'

A description of the data is shown in Table 3.1 and the statistical description of the data is listed in Table 3.2.

Table 3.2: Descriptive Statistics of Original Variables

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
RPS Features					
rps	50	.7	.46291	0	1
Energy Generation Variables					
trenetgen	50	7713.37	16142.97	.5	84510
msw	50	259250.5	445583.3	0	1824337
otherbio	50	19421.19	55346.61	0	275651
wood	50	206641.1	472662.4	0	2564861
geo	50	291360.6	1818452	0	$1.28 * 10^7$
hydro	50	5725078	$1.43 * 10^7$	0	$8.19 * 10^7$
solarpv	50	10154.12	69929.8	0	494572
wind	50	531782.7	1226206	0	6670515
netgen	50	$8.12 * 10^7$	$7.40 * 10^7$	5967725	$4.01 * 10^8$
Geographical variables					
east	50	.26	.4430875	0	1
Political variables					
govd	50	.44	.5014265	0	1
represen	50	9.02	9.692181	1	53
henvscore	50	44.6807	18.65746	0	96.25
Economic variables					
population	50	5976420	6662378	515000	$3.65 * 10^7$
incpercap	50	61113.84	9300.077	44769	82404

Table 3.2 – Continued on the next page

Table 3.2 – Continued from the previous page

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
gdp[6]	50	260635.3	314765.7	23628	1742172
Electricity market variables					
price	50	8.842857	3.322409	4.92	20.72
Pollution variables					
CO_2	50	49193.98	46918.3	10	257552
SO_2[7]	49	194.3469	236.5193	1	970
NO_2	49	77.5102	61.27198	2	260

Regarding the RPS data, the information collected about the policy design includes: the type of target (mandatory or non-mandatory), the mechanism for complying with the target (the use of REC or not), the type of utility to which the target is applied, whether the target can be complied with importing energy from other states or other regions, the compliance year, ultimate target generation within the region, whether the RPS allows a utility to buy electricity from generators outside of the state, the capacity of currently installed generation, whether the electricity will be transmitted directly to the customers, and whether all the electricity generated using renewables must be generated within the NERC region of the electric grid (see Fig. 3.1) to which a state belongs (Wiser and Barbose, 2008). This specific information is summarized in Table 3.3. Detailed information about rules, regulations and policies for the RPS, for each state, were obtained from the DSIRE[8] and from the LBNL[9]. As already mentioned, some RPS policies include REC trading as a valid means to comply with the requirements of the policy. For the purpose of this thesis REC trading is not considered in the numerical analysis.

[6] GDP of the state
[7] VT does not data for emission of CO_2 and SO_2
[8] by North Carolina Solar Center, (last accessed 05/20/2009).
[9] "RPS in the USA A status report with date through 2007."

Table 3.3: Selected Design Elements of State RPS Policies (Wiser and Barbose, 2008)

State	First Compliance Year	Current Ultimate Target	Existing Plants Eligible	Set-Asides, Tiers, or Minimums	Credit Multipliers
Mandatory RPS Obligations					
AZ	2001	15% (2025)	No	Distributed Generation	None
CA	2003	20% (2010)	Yes	None	None
CO	2007	20% (2020): IOUs 10% (2020): POUs	Yes	Solar	In-State, Solar, Community Ownership
CT	2000	23% (2020)	Yes	Class I/II Technologies	None
DE	2007	20% (2019)	Yes	Solar, New/Existing	Solar, Fuel Cells Wind
HI	2005	20% (2020)	Yes	Energy Efficiency	None

Table 3.3 – Continued on the next page

Table 3.3 – Continued from the previous page

State	First Compliance Year	Current Ultimate Target	Existing Plants Eligible	Set-Asides, Tiers, or Minimums	Credit Multipliers
IL	2008	25% (2025)	Yes	Wind	None
IA	1999	105 MW (1999)	Yes	None	None
ME	2000	40% (2017)	Yes	New/Existing	None
MD	2006	9.5% (2022)	Yes	Solar,	Class I/II Technologies
MA	2003	9% (2014)	No	None	None
MN	2002	25% (2025) 30% (2020): Xcel	Yes	Wind for Xcel; Goal for Community-Based Renewables	None
MT	2008	15% (2015)	No	Community Wind	None
NV	2003	20% (2015)	Yes	Solar, Energy Efficiency	PV, DG,Eff, Waste Tire
NH	2008	23.8% (2025)	Yes	Solar, New, Existing Biomass/	None

Table 3.3 – Continued on the next page

Table 3.3 – Continued from the previous page

State	First Compliance Year	Current Ultimate Target	Existing Plants Eligible	Set-Asides, Tiers, or Minimums	Credit Multipliers
				Methane, Existing Hydro	
NJ	2001	22.5% (2021)	Yes	Solar, ClassI/II Technologies	None
NM	2006	20%(2020): IOU 10%(2020): Co-ops	Yes	Solar, Wind, Geothermal or Biomass, Distributed Generation	None
NY	2006	24%(2013)	Yes	Distributed Generation	None
NC	2010	12.5%(2021): IOUs 10% (2018)	Yes	Solar, Swine waste, Poultry Waste, Energy Efficient	None
OR	2011	25%(2025) Large 5-10%(2025)	No	Goal for community-based and small-scale	None

Table 3.3 – Continued on the next page

Table 3.3 – Continued from the previous page

State	First Compliance Year	Current Ultimate Target	Existing Plants Eligible	Set-Asides, Tiers, or Minimums	Credit Multipliers
		Small		renewables	
PA	2001	8%(2020)	Yes	solar	None
RI	2007	16%(2019)	Yes	New/existing	None
TX	2002	5.880MW(2015)	Yes	Goal for non-wind	All Non-Wind
WA	2012	15%(2020)	No	None	Distributed Generation
DC	2007	11%(2022)	Yes	Solar, Class I/II Technologies	Wind, Solar, Methane
WI	2000	10%(2015)	Yes	None	None
Non-Biding Renewable Energy Goals					
MO	2012	11%(2020)	Yes	None	PSC Authorized To Do So
ND	2015	10%(2015)	Yes	None	None
VT	2006	Up To 10%(2012)	No	None	None
VA	2010	12%(2022)	Yes	None	Wind, Solar

Most of the data related to energy variables were collected from EIA. See Table 3.4. Variables representing the existing infrastructure for renewable electricity generation, include the renewable sources for electricity generation such as wind, biomass, geothermal, and water in the case of hydrogeneration. In addition, information such as the renewable installed electricity generation, the energy consumption per person, the ethanol production, and the coal production by state, were obtained from the EERE. In particular, the data was taken from the Renewable Energy Data Book, which compiles data from EIA, Navigant consulting, American Wind Energy Association (AWEA), Geothermal Energy Association (GEA), and the NREL. The information taken from the EIA, see Table 3.4, includes the renewable electricity generation by state, the total net summer renewable capacity (in megawatts (MWs)), the total renewable net generation (in thousands of MWh), and the renewable electric power net generation in 2006 (in MWh). The specific renewable sources considered for electricity generation are MSW, other biomass, wood, geothermal, hydroelectric conventional, solar photovoltaic, and wind.

The geographical information is related to the NERC regions (see Fig. 3.1). NERC divides the country in three main zones: East, West and Texas. Each zone has different characteristics related to the grid infrastructure including transmission connections between the states, quantity of generation using fossil fuels, consumption per person, etc. The eastern part of the country has a high presence of transmission lines. This large number of lines is a consequence of the high population level and industrialization in those states. The West has few transmission interconnections and less population than the eastern part of the country. Due to the fact that Texas is only one state, the NERC region, is coded using a dummy variable as follows: *east*=1 if the state is in the east NERC and *east*=0 otherwise. The geographical information was collected from the following sources: the NERC, the EIA, and a transmission report from the Department of Energy (DOE)[10].

[10]National Transmission Grid Study, the honorable Spencer Abraham, Secretary of En-

Table 3.4: EIA Energy Tables by State

Table Number	**Information**
1.18	Renewable Electric Power sector Net Generation by source and State 2006, (in thousand of Kilowatts) information released on July 2008
1.19	Renewable Commercial and Industrial Sector Net generation by Energy Source and State 2006, (in thousand of kilowatts) information released in July 2008
1.19	Renewable Commercial and Industrial Sector Net generation by Energy Source and State 2006, (in thousand of kilowatts) information released in July 2008
1.19	Renewable Commercial and Industrial Sector Net generation by Energy Source and State 2006, (in thousand of kilowatts) information released in July 2008
1.20	Total Renewable Net Generation by Energy Source and State, 2006, (in thousand of kilowatts)
1.24	Renewable Electric Power Sector Net Capacity by Energy Source and State, 2006, (in Megawatts)

The data related to political variables quantifies the state policy-makers' percentage of approval of pro-environmental laws. Such information was taken from the National Environmental Scorecard published by the League of Conservation Voters (LCV). The variable *henvscore* represents the percentage of pro-environmental laws voted for each state representative in 2006. The other political variable, which is denoted by *govd*, codes each state's Governor's political party in 2006. The variable *govd* was treated as a dummy variable, where a value 0 represents a republican senator and the value 1 represents a democratic senator.

It is well known that the electricity demand is strongly correlated with the GDP. Since the electricity demand data is not easily available, GDP was used as a proxy variable for the electricity demand. The total population for each state in 2006 was taken from the U.S. Census Bureau as well.

ergy U.S. Department of Energy, May 2002.

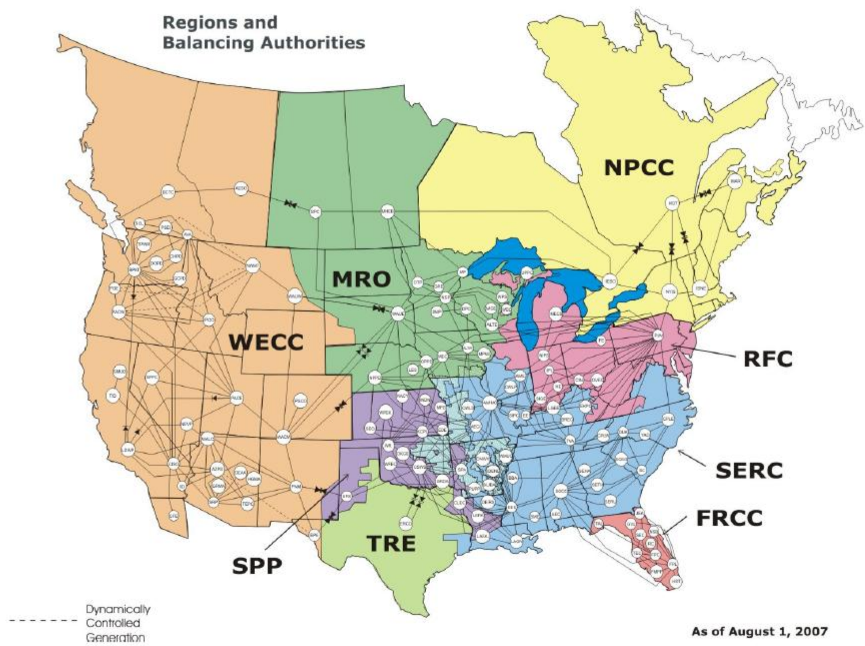

Figure 3.2: NERC Regions and Balancing Authorities. The map reflects the degree of interconnection for each region. (Source: http://www.nerc.com, (last accessed 12/01/2009))

Regarding electricity market variables, the data considered in this analysis are: the electricity price per KWh, the net electricity generation, the main fuel used for electricity generation, and the council authority. The source of this information is the EIA.

Finally, this study considers pollution variables. A major environmental problem is emissions produced by fossil fuels combustion during electricity generation. Emissions of SO_2, NO_2, and CO_2 are the pollutants considered in this work. Data on air pollution produced by GHG emissions in 2006 were found from EIA. The data employed in this work considers only emissions produced during the generation of electricity.

A description of the data is shown in Table 3.1 and the statistical description of the data is listed Table 3.2. The District of Columbia and the state of Hawaii are not listed in these tables because they have not been considered in this analysis. In addition, information on the emission of SO_2 and NO_2 for the state of Vermont is not available.

Based on these variables several new variables were generated. The variable *rpstarget* was generated combining the dummy variable *rps* (see Table 3.2) with the variable ultimate target (see Table 3.3) in order to create the dependent variable. In the analysis, this variable incorporates more information than the binary variable *rps*. The variable *rpstarget* represents the specific information about the target value and the presence of the RPS policy in the state. Also, the variable *gdpcapita* was created by taking the ratio between the *gdp* and the total population of the state. In addition, a variable quantifying the relative amount of fossil fuel used in the generation of electricity (*perfossil*) was generated using the total amount of generated energy. Table 3.5 presents a statistical description of the new variables created from the original variables listed in Table 3.2. The variables listed in Table 3.5 correspond to the set of variables used to investigate which variables explain adoption and ultimate target for states' RPS in the U.S..

Table 3.5: Summary Statistics of the New Variables [11]

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
		RPS			
rps	50	.7	.4629	0	1
rpstarget	50	11.5560	10.3098	0	40
		Energy Generation Variables			
biomass	50	.0081	.0209	0	.1101
perfossil	50	88.1074	20.1722	14.1802	100

Table 3.5 – Continued on the next page

Table 3.5 – Continued from the previous page

Variable	Obs	Mean	Std. Dev.	Min	Max
perhydro	50	10.0018	19.5893	0	83.9855
perwind	50	.7181	1.1594	0	5.0960
retotal	50	7043698	$1.60 * 10^{07}$	0	$8.38 * 10^{07}$
Geographical Variables					
east	50	.26	.4431	0	1
Political Variables					
henvscore	50	44.6807	18.6575	0	96.25
govd	50	.44	.50143	0	1
Economical Variables					
gdp	50	260635.3	314765.7	23628	1742172
gdpcapita	50	36.0875	6.6217	24.062	59.288
population	50	5976420	6662378	515000	$3.65 * 10^{07}$
Electricity Market Variables					
price	50	8.842857	3.322409	4.92	20.72
Pollution Variables					
no2	49	77.5102	61.2720	2	260
so2	49	194.3469	236.5193	1	970

3.3 Econometric Model

To investigate the factors that effect adoption of and ultimate target for RPS policies in the U.S. I formulate an econometric model using the new variable *rpstarget* which represents the percentage of electricity generated using renewables in order to reach as a RPS's goal by each state that adopted the RPS. Because the variable *rpstarget* falls into the category of a corner solution response variable, a Tobit model is applied in the analysis.

The variables investigated are associated with factors believed to be affect RPS adoption. Those variables are:

- Political: *henvscore* and *govd*. The variable *henvscore* represents the percentage of pro-environmental laws approved by the House of Representatives in Washington D.C. for each state. Based on the assumption that representatives tendency in the state is to approve environmentally friendly laws, state policymakers will be inclined to approve a policy to incentivize the use of renewable resources in electricity generation. Thus, it is expected that the *henvscore* coefficient will be positive. The variable *govd* represents a Governor's political party as a dummy. If the Governor is a Democrat *govd* is one, and zero otherwise. It is expected that the Governor's political party may be an important variable in the analysis, and can influence RPS adoption.

- Geographical: *east*. The East region is expected to be an important proxy of specific technical and economic characteristics of the electricity market and the power grid, including transmission infrastructure, electricity market transactions, interconnection between states, level of industrialization, electricity demand, etc. A high level of industrialization yields a large amount of pollution in the region. Also, such level of industrialization demands a large number of interconnections between the transmission lines, thereby facilitating the REC transactions activities. This variable is expected to have a positive impact on the adoption of the RPS because most of the states in the eastern part of the U.S. have a large number of interconnected transmission lines because of the high level of industrialization. The large number of transmission lines is a base for the developing REC market, a good alternative for the local utilities to comply the RPS's target[12]. Then the east states adopting an RPS policy could decrease the local emissions from generation plants.

- Related to Energy infrastructure variables: *perfossil, perhydro,* and *perwind* were generated. These variables represent the percentage of electricity generated using fossil fuels, hydropower, and wind, respectively. Most of the states generate the majority of their electricity using coal or gas. Moreover, some of them are also producers of coal or gas; which can lower the cost of electricity generation. It is believed that the *perfossil* variable will have a negative impact on the adoption of the RPS, because adopting the policy would require an investment in infrastructure for renewable energy generation, and simultaneously, decreasing the demand for fossil fuels, causing a negative economic impact on the state. The *perhydro* variable is of interest because there are some states where a high percentage of their electricity generation is from hydropower generation. If these states adopt the RPS policy, power generators will have an opportunity to sell their extra energy production to other states with a strict mandatory RPS policy. For this reason, the RPS policy of each state specifies whether hydropower generation is accepted as a renewable energy source to comply the policy target. Recall that the variable *perwind* represents the percentage of electricity generated using wind. Only the state of Texas has the resources and conditions to reliably generate electrical energy using wind while complying with an RPS target. I would expect a positive sign for *perwind.*

- Related to electricity market: *price.* The variable *price* represents the average price per KWh in each state. Adopting an RPS policy in a state would need to increase the investment in new technologies to generate electricity using renewables or purchase from out of state and this will increase the electricity price. Clearly this is not a popular measure, and it is expected to have a

[12]If the state adopt an RPS where the utilities can comply only buying RECs from the state which adopted the policy and not form others.

negative impact on the adoption of an RPS policy.

- Other economic variables: starting from the variables *gdp* and *population*, the new variable *gdpcapita* has been generated, where *gdpcapita* represents the GDP per capita in each state. In economic analysis, the GDP is usually employed as an education proxy. Like Huang in 2007, following the concept of the environmental Kuznet's inverted "U"hypothesis. I would expect to have a positive impact on the adoption of the RPS policy for *gdpcapita* (Huang et al., 2007).

- Variables for pollution levels: *no2* and *so2*. The *no2* and *so2* are variables associated with the combustion of fossil fuels used in electricity generation. If the concentration of the GHG emission is high, people will be aware of the consequence of pollution and will apply pressure on the policy-makers to approve an RPS policy.

The statistical summary of the variables used in the analysis are listed in the Table 3.5.

A Tobit model is applied under the assumptions that errors are normally distributed and homoskedastic.

$$rpstarget_i = f(perfossil_i, perhydro_i, perwind_i, east_i, henvscore_i, govd_i, price_i, gdpcapita_i, no2_i, so2_i) + \epsilon_i. \quad , \; with \;\; i = 1, ..., N \tag{3.1}$$

The notation used by Cameron and Trivedi (2009) has been adopted here to specify a Tobit model for the observed dependent variable *rpstarget*. The $y_i = rpstarget_i$ is a function of the independent variables, X_i, $i = 1, \ldots, 9$, where $X_1 = perfossil$, $X_2 = perhydro$, $X_3 = perwind$, $X_4 = east$, $X_5 = henvscore$, $X_6 = gdpcapita$, $X_7 = govd$, $X_8 = no2$, and $X_9 = so2$.

The observed latent variable, y^*, in the Tobit econometric model representation is shown in

$$y_i^* = \mathbf{X}_i\beta + \varepsilon_i,\ \ i = 1, ..., N \tag{3.2}$$

where $\varepsilon_i \sim N(0, \sigma^2)$, and $\mathbf{X}_i$ denotes the (9 x 1) vector of exogenous and fully observed regressors. The observed variable y_i is related to the latent variable y_i^* through the observation rule represented in equation 3.3:

$$y = \begin{cases} y_i^* & \text{if } y_i^* > L \\ L & \text{if } y_i \leq L \end{cases},\ \ i = 1, ..., N. \tag{3.3}$$

The definition of $y_i = rpstarget$ is shown in equation (3.4). Where $L = 0$ is the corner response value when the target does not exist for a given state because the state has not adopted an RPS. So, the relationship between the observed variable and the unobserved variable in the Tobit model is represented by:

$$rpstarget_i = \begin{cases} rpstarget_i^* & \text{if } rpstarget_i^* > 0 \\ 0 & \text{if } rpstarget_i \leq 0 \end{cases},\ \ i = 1, ..., N \tag{3.4}$$

In general, the probability of a corner response observation is represented in the equation

$$Pr(y_i^* \leq 0) = Pr(\mathbf{X}_i\beta + \varepsilon \leq 0) = \Phi\left(\frac{\mathbf{X}_i\beta}{\sigma}\right), \tag{3.5}$$

where $\Phi(\cdot)$ is the standard normal cumulative distribution function. Specifically, in the Tobit model setting used here, $L = 0$, and the probability of a corner response observation is presented as:

$$Pr(y_i^* \leq 0) = Pr(\mathbf{X}_i\beta + \varepsilon \leq 0) = \Phi\left(\frac{\mathbf{X}_i\beta}{\sigma}\right). \tag{3.6}$$

The expected value of the observed variable y for the non-zero observations is shown in 3.7:

$$E(y_i|\mathbf{X}_i, y_i > 0) = \mathbf{X}_i\beta + \sigma\frac{\phi\left(\frac{\mathbf{X}_i\beta}{\sigma}\right)}{\Phi\left(\frac{\mathbf{X}_i\beta}{\sigma}\right)'}, \tag{3.7}$$

where $\phi(\cdot)$ is the standard normal density and $\Phi(\cdot)$ is the standard normal cumulative distribution function.

When a Tobit model has a corner response data with $L = 0$, the density function has two components, the positive and zero observations with $d = 1$ and $d = 0$ respectively (Cameron and Trivedi, 2005):

$$f(y_i) = \left(\frac{1}{\sqrt{2\pi\sigma^2}}\exp\left(-\frac{1}{2\sigma^2}(y_i - \mathbf{X}_i\beta)^2\right)\right)^{d_i}\left(1 - \Phi\left(\frac{\mathbf{X}_i\beta}{\sigma}\right)\right)^{1-d_i}. \tag{3.8}$$

In the equation (3.8) the second term represents the likelihood of the corner response observation. The maximum likelihood estimates (β, σ^2) solve the first order conditions from the maximization of the log-likelihood based on the density function in equation (3.8)[13]. The log-likelihood function for each observation i is shown in equation (3.9) (Wooldridge, 2006):

$$LL_i(\beta, \sigma) = \begin{cases} \ln\left(1 - \Phi\left(\frac{\mathbf{X}_i\beta}{\sigma}\right)\right) & , \quad y_i = 0 \\ \ln\left(\frac{1}{\sigma}(y_i - \phi\left(\frac{\mathbf{X}_i\beta}{\sigma}\right)\right) & , \quad y_i > 0 \end{cases}. \tag{3.9}$$

3.4 Analysis

3.4.1 Regression Results

Using a sample of 48 out of the 50 observations for each variable listed in Table 3.5, the vector of estimated β coefficients for the Tobit model has been computed. It

[13] The optimization was solved using the software STATA version 10.1 on a computer equipped with an Intel(R) Core(TM) 2 Duo T6400 processor running at 2.00 GHz, a RAM of 4 GB, and a 64-bits operating system.

must be noted that the analysis does not include DC neither the states of HI and VT. DC is not included because there is no information for the variable *henvscore*. The state of HI is not included in the geographical area because is not part of the continent, and the state of VT is not included because there is no information for the variables *no2* and *so2* from this state.

The calculation of the covariance/correlation of the $\widehat{\beta}$ was performed by enabling the option of robust calculation of such matrix. The calculated parameters for the Tobit regression model as well as the t-statistics of the model are listed in the Table 3.6.

Table 3.6: Estimation Results: A Tobit Model

Tobit regression					Number of obs. = 48
					F(10, 38) = 5.21
					Prob $> F$ = 0.0001
Log pseudolikelihood = -130.08419					$PseudoR^2$ = 0.1217
		Robust			
rpstarget	Coef.	Std. Err.	t	$P > \|t\|$	[95% Conf. Interval]
perfossil	**-2.3061*****	.8357	-2.76	0.009	-3.9978 -.6144
perhydro	**-2.2846*****	.8409	-2.72	0.010	-3.9868 -.5824
perwind	-1.0406	1.472974	-0.71	0.484	-4.0224 1.9413
east	**7.5828***	4.031	1.87	0.069	-.6275 15.6931
henvscore	**.3143*****	.0910	3.45	0.001	.1299 .4986
govd	.2858	3.185414	0.09	0.929	-6.1627 6.7344
gdpcapita	**.0004***	.0002	1.73	0.091	-.0001 .0011
price	.3250	.5484	0.59	0.557	-.7852 1.4351
no2	-.03561	.0404	-0.88	0.383	-.1173 .0461
so2	.0151	.0143	1.06	0.297	-.0138 .0440
constant	**202.8698****	81.24664	2.50	0.017	38.39461 367.345
/sigma	9.0367	.8962			7.2225 10.8509
Obs. summary:					15 left-censored observations at $rpstarget \leq 0$
					33 uncensored observations
					0 right-censored observations

Significant at: * 10%, ** 5%, and *** 1%

It can be seen from the results for the Tobit model shown in Table 3.6 that three variables are significant at the 1% level, one variable is significant at the 5% level, and two variables are significant at the 10% level. These significant variables are *perfossil*, *perhydro*, *east*, *henvscore*, *gdpcapita*, and the *constant*.

- The variable *perfossil* has a negative sign and is significant at 1%. The *perfossil* variable represents the percentage of electricity generated using fossil fuels, specifically coal. A negative sign for the coefficient of *perfossil* indicates that states where a large percentage of electricity generation comes from fossil fuels, will be less inclined to adopt an RPS policy, or to establish a high RPS target. A possible explanation is that states with high portion of electricity generation using fossil fuels are also producers of those fuels, or are geographically close to producers of coal, gas or oil. Moreover, in coal-rich states political pressure may exist to sustain the fossil fuel industry.

- The variable *perhydro* has a negative sign and is significant at the 1% level. The *perhydro* variable represents the percentage of electricity generated using hydropower in the state. An explanation for the negative sign in the coefficient associated with *perhydro* is related to the investment in new technologies. Usually states with high percentage of electricity coming from hydropower generation do not experience a high level of air pollution from electricity generation. They may not feel inclined to invest in new expensive technologies for generation of electricity using renewables, such as solar, wind and geothermal. States with high percentage of hydropower generation may perceive RPS adoption as an business opportunity of selling "clean electricity" to other states in the form of a REC. Usually buyer states have a mandatory RPS with a high target and high levels of air pollution and they do not have enough capacity to generate the amount of clean electricity required to comply their RPS state target. Moreover, only small hydropower generation plants are considered as "clean electricity generators" (at most 20 MW), while large hydropower plants are typically not supplying power that can be used for RPS compliance whether it is for own use or for sale as a REC.

- The variable *east* has a positive sign and is significant at the 10% level. Recall that the variable *east* is a proxy of specific technical and economical characteristics of the electricity market. This variable was expected to have a positive impact on the adoption of an RPS policy because the eastern region of the U.S. has a large number of transmission interconnections, which are needed to develop a REC market. Thus, the geographical location will have a positive influence in the adoption of the RPS.

- The variable *henvscore* has a positive sign and is significant at the 1% level. States with house representatives that approve a high percentage of environmental laws will also be more inclined to approve an RPS policy.

- The variable *gdpcapita* has a positive sign and is significant at the 10% level. A higher GDP per capita is associated with high education levels, which implies that the population may be more concerned about pollution problems. Also, a higher the GDP per capita means people are better able to pay for increased power prices after the implementations of an RPS.

- The last significant variable is the constant, which is significant at the 5% level. The constant includes the effect of all those variables not included in the regression. These variables have not been included here for several reasons, one reason is being the limited number of observations. With additional variables, the degree of freedom is quickly observed.

Some variables that are of interest to include were not significant, but important for the RPS adoption. One of these variables is *perwind*, which represents the percentage of the electricity generated using wind in each state. It must be noted that most of the states do not have good conditions to permanently and reliably generate amounts of electricity using wind. An exception is Texas, which has favorable conditions and resources for investing in the technology needed for using wind to generate electricity. Most other states do not consider wind generation as a factor of influence in the decision to adopt an RPS policy in the state or use wind to comply the RPS's target. The others not significant variables are *govd*, *price*, *no2*, and *so2*.

The results of the regression show that Tobit model has a pseudo (Mc Fadden) R^2 metric equal to 0.1217. However, it is well-known that this result metric does not represent accurately the statistical significance level of the model (Cameron and Trivedi, 2009, 2005; Baum, 2006). In addition an R^2 metric, which is denoted here as ρ^2, was calculated as squared correlation between the predicted dependent variable predicted and the observed dependent variable. It must be mentioned that this ρ^2 value is somewhat comparable to the standard R^2 metric for the statistics of the residual errors in an ordinary least squares (OLS) regression (Wooldridge, 2006). For the data used in this work, the computed ρ^2 is 0.5482. (The complete result provided by Stata for ρ^2 is shown in the Table 3.7.) A OLS regression was also estimated in order to compare those results with the results of the Tobit model. It must be highlighted that since both models rely on different mathematical assumptions, a direct comparison is impossible. Table 3.8 lists the coefficients for the Tobit and the OLS regression models. It can be observed that the coefficients of the significant variables in both models have the same sign and roughly the same significance.

Table 3.7: ρ^2 Value

Correlate xb rpstarget (obs=48)		
	xb	rpstarget
xb	1.0000	
rpstarget	0.7404	1.0000
display $r(\rho^2) = 0.54824064$		

In this thesis the explanatory variables considered are socioeconomic, political,

Table 3.8: OLS and Tobit Models

Model	**OLS**	**Tobit**
Variable		
perfossil	-2.09***	-2.31***
perhydro	-2.08**	-2.28***
perwind	-1.37	-1.04
east	5.55*	7.53*
henvscore	.212***	.314***
govd	.497	.286
gdpcapita	.00031*	.00039*
price	.119	.325
no2	-.0372	-.0356
so2	.0123	.0151
constant	195**	203**
sigma		9.04
ρ^2	0.5559	0.5482
log-likelihood		-130
Significant at: * 10%, ** 5%, *** 1%		

and environmental; however, these variables are not the same as those used by Huang *et al.* (2007) in their work. Huang *et al.* used in their analysis the following variables: the gross state product, the population growth rate, the level of education, the political party dominance, the expenditure on natural resources and the share of coal in electricity generation. None of these variables are used here. Comparing the variables among the two studies, it can be noted that only the gross state product is similar to an explanatory variable used here: the GDP per capita. Given that similarity, I can compare the effect of both variables on the adoption of an RPS by a state. It turns out that both studies reach the same conclusion: the effect of the GDP and the gross state product is positive on the adoption of an RPS by state. This reinforces the idea that states with larger GDP will be more concerned about the environment and the use of renewable energy in electricity generation (Huang et al., 2007).

The political variable in Huang's work is a dummy equal to one when the majority of the state's representatives in the Senate and the House are republican. This political variable is significant with a negative sign; states with majority of republican representatives both Houses of congress are less likely to adopt an RPS policy. In this thesis, the political variable represents the percentage of environmental approved laws by the House's representatives in each state regardless of the political party dominance. Here the variable *henvscore* is significant, i.e., a state with representatives approving a large percentage of environmental laws is more likely to adopt a RPS policy. As we can see, the Huang *et al.*'s political variable, political party dominance in the state, and the *henvscore* are different variables and cannot be compared in a direct fashion.

3.4.2 Marginal Effect Estimates

After running the Tobit model with corner response data, some post-estimation analysis and model diagnostic tests were conducted in order to predict a range of quantities, the default linear prediction produces the sample fitted values of the unobserved (latent) variable y^* for all observation (Cameron and Trivedi, 2009). According to Cameron and Trivedi (2009), the latent variable mean is represented by

$$\frac{\partial E(y|X, y > 0)}{\partial X} = 1 - \omega\lambda(\omega) - \lambda(\omega)^2\beta \tag{3.10}$$

with $\omega = X'\beta/\sigma$ and $\lambda(\omega) = \phi(\omega)/\Phi(\omega)$.

First, the marginal effects of the regression coefficients are calculated. Results for the marginal effects are shown in Table 3.9. Regressors with significant marginal effects correspond to the same variables appearing as significant in the Tobit model, and also, have the same sign. These variables are *gdpcapita* and *east* significant at the level of 10%, while *perfossil*, *perhydro*, and *henvscore* are significant at the level 1%. From these results for the marginal effect, it can be concluded that: (i) when the regressor *gdpcapita* increases in 1%, such increment affects the *rpstarget* positively increasing it by 0.03%; (ii) the regressor *east*, a dummy variable, shifts up the intercept point of the dependent variable *rpstarget* in 5.22 units when *east* changes from zero to one [14]. (iii) when the regressor *perfossil* increases in 1%, such increment affects the *rpstarget* negatively decreasing it by 1.47%; (iv) when the regressor *perhydro* increases in 1%, its effect on the dependent variable *rpstarget* is to decrease it by 1.46%; and (v) when the regressor *henvscore* increases in 1%, such increment affects the *rpstarget* by increasing it 0.2%, approximately.

Table 3.9: Marginal Effects

Marginal Effects After Tobit
$y = E(rpstarget|rpstarget > 0)(predict, e(0,.))$
$y = 11.822108$

variable	dy/dx	Std. Err.	z	$P > \|z\|$	[95% C.I.]		X
perfossil	**-1.4743*****	.5630	-2.62	0.009	-2.5778	-.3708	88.222
perhydro	**-1.4606*****	.5676	-2.57	0.010	-2.5729	-.3482	9.9398
perwind	-.6652	.94951	-0.70	0.484	-2.52622	1.1958	.7449
east†	**5.2263***	3.0553	1.71	0.087	-.7621	11.2146	.2708
henvscore	**.2009*****	.0559	3.60	0.000	.0915	.31042	44.7232
govd†	.1829	2.0373	0.09	0.928	-3.8101	4.1758	.4583
gdpcapita	**.0003***	.00014	1.75	0.080	-.00003	.0005	36136.3
price	.2077	.3485	0.60	0.551	-.4754	.8909	8.7902
no2	-.0227	.0261	-0.87	0.384	-.0740	.0285	76.4167
so2	.0096	.0092	1.05	0.296	-.0084	.02772	184.125

(†)dy/dx is for discrete change of dummy variable from 0 to 1
Significant at: * 10%, ** 5%, *** 1%

3.4.3 Test for Normality and Homoskedasticity

Tests for the normality and homoskedasticity of the residual errors were conducted in order to check the validity of the assumptions of the Tobit model. The pro-

[14]The marginal effect of the dummy variable *east* must be analyzed differently as in the case of continuous regressors. This effect is obtained as the difference between $E(rpstarget|east, rpstarget > 0)$, with *east*=0 and *east*=1.

cedure to conduct these tests was obtained from Cameron and Trivedi (2009). It must be highlighted that for a Tobit model the standard tests for the normality and homoskedasticity of the errors, such as those implemented in the Stata commands *sktest* and *hettest*, cannot be employed (Cameron and Trivedi, 2009).

First, to test for normality is it necessary to compute the generalized residuals. Using the value of the Mills' ratio for each regressor, λ_i, the residuals are computed assuming that the dependent data has a corner response at $L = 0$. The generalized residuals are then computed in order to employ conditional moment tests. Specifically, the first four conditional moments must be calculated. The theory for this test was taken from Cameron and Trivedi (2005). Where "the first order conditions for censored Tobit MLE suggest conditional moment test based on the generalized residual" (Cameron and Trivedi, 2005, pp. 544).

$$e_i = d_i \frac{y_i - \mathbf{X}_i \beta}{\sigma^2} - (1 - d_i) \frac{\phi_i}{\sigma(1 - \Phi_i)} \tag{3.11}$$

"If the Tobit model is correctly specified then $E[e_i|\mathbf{X}_i] = 0$ since the regularity conditions imply that $E[\partial lnf(y_i)/\partial\beta] = 0$" (Cameron and Trivedi, 2005, pp. 544). Then, an *m-test* must be implemented, where the null-hypothesis is $H_0 : E[e\mathbf{Z}] = 0$ and the alternative hypothesis is $H_0 : E[e\mathbf{Z}] \neq 0$. Generalized residuals for the Tobit regression, as discussed in Cameron and Trivedi (2005), were computed. The results for the generalized residuals are shown in Table 3.10. It must be noticed that the generalized residuals are not close enough to zero, (Cameron and Trivedi, 2009). Using the log-likelihood "scores," the Stata program can compute $\widehat{\lambda}_i, X_i$ using an auxiliary regression with a constant value equal to one [15].

The final result obtained for the NR^2 statistic is NR^2= 47.936125 with p-value = $3.898 * 10^{-11}$. This value means a strong rejection of the null hypothesis of normality distribution of the errors (Cameron and Trivedi, 2009). The reason for this problem could be the small data size used in this work, and also, the effect of the omitted

[15] Details are explain in (Cameron and Trivedi, 2009)

significant variables which are absorbed by the constant of the model. The coding for the generalized residuals 1 is *gres1* and in the same way were namely the generalized residuals 2,3 and 4.

Table 3.10: Summarize generalized residuals

Variable	Obs	Mean	Std. Dev.	Min	Max
gres1	48	.2534	.8102	-1.6487	2.0657
gres2	48	-.2930	.9716	-.9915	3.2670
gres3	48	.5408	1.9853	-4.4812	8.8143
gres4	48	-1.5758	3.4895	-2.9999	15.2074

In order to double check the results of the normality test, an alternative test for normality was conducted. Specifically Drukker (2002) developed a procedure to correct distortions generated in the test provided by Cameron and Trivedi (2009). The procedure tests the null hypothesis of normal distribution of the errors and it is implemented in the Stata command *tobcm*[16]. The result of this alternative test is shown in the Table 3.11, and confirms that the errors are not normally distributed.

Table 3.11: Pseudo R^2

Conditional moment test against the null of normal errors	
CM	Prob $> \chi^2$
10.611	0.00496

Next, the presence of homoskedasticity in the Tobit model was tested. The test was conducted using the generalized residuals and the procedure described in (Cameron and Trivedi, 2009). Since the test assumes a null hypothesis for the presence of homoskedasticity, according to the result obtained, this hypothesis is strongly rejected. As a consequence, the residual errors exhibit heteroscedasticity, that is, the variance of the residual errors are different between each other.

[16]The Stata command *tobcm* can only be used when the dependent variable is censored at or has a corner response at zero, as in the case treated here.

Since the underlying assumptions of the Tobit model are not satisfied, one may argue that the Tobit model is not an appropriate representation of the data. Wooldridge (2006) presents an informal procedure to test the suitability of the Tobit model. The procedure consists in fitting a Probit model, where the value zero is given for all those values at the left corner data and the value one is for the values greater that the value of left corner. Note that for the case under analysis, this case is fitting a Probit model where the dependent variable is the original dummy variable *rps*. Once the Probit model is calculated, the coefficients of such model (denoted by γ_i) can be used to indicate if the Tobit model is appropriate.

The procedure by Wooldridge (2006) suggest that if a Tobit model holds, then one can roughly estimate the coefficients of a Probit model (denoted by $\hat{\gamma}_i$), which uses exactly the same regressors as the Tobit model, by taking the ratio between the coefficients of the Tobit model, and the standard deviation of the residual errors (Wooldridge, 2006). In Table 3.12 the estimated coefficients (estimated using the Tobit model) as well as the actual coefficients of the Probit model are shown. This estimation will never be perfect due to sampling errors; however, consistency between the order of magnitude and the sign of the significative coefficients must be found (Wooldridge, 2006). If the estimates are not consistent with the actual coefficients, there is an indication that the Tobit model does not hold. From Table 3.12 it can be observed that the significant coefficients of the Probit model and their estimates, which are calculated using the coefficients of the Tobit model and the standard deviation of the errors, have the same sign and have roughly the same order of magnitude. In summary, according to the procedure presented by Wooldridge it can be (informally) concluded that the Tobit model is an appropriate representation of the data (Wooldridge, 2006). However, because of lack of normality the hypothesis test may provide the wrong conclusions about the factors that affect states adoption of an RPS.

Table 3.12: Comparison between regression coefficients of a Tobit and a Probit model

	Tobit model $\hat{\gamma}_i = \beta_i/\sigma$	Probit model γ_i
perfossil	-0.3150**	-1.3757
perhydro	-0.3121**	-1.3605
perwind	-0.1421	-0.7523
east	1.0289	0.9707
henvscore	0.0429**	0.0733
govd	0.0390	-0.5107
gdpcapita	0.00005	0.00004
price	0.0444	0.2450
no2	-0.0049	0.0063
so2	0.0021	-0.0012
_cons	27.7107*	130.6430
Significant at: * 5%, ** 1%, and *** 0.1%		

Chapter 4

Conclusions and Future Work

4.1 Conclusions

The Tobit regression model may be the most appropriate model for representing the corner solution data type associated with the RPS goal studied in this thesis because of the high proportion of zeroes. However, the Tobit model is only capable of yielding reliable regression results and hypothesis test if errors are normally distributed and homoskedastic.

For the Tobit model obtained in this thesis work, the regression errors do not satisfy the conditions of normality of errors and homoskedasticity. Since the regression errors do not satisfy the underlying assumptions of the Tobit model, this indicates that data collected exhibits problems that affects the model results. The major problems faced during the data collection are the low number of observations and that some crucial data are not available, such as information on investment in renewable generation, transmission conditions in the states, and REC trading.

An estimate of the representability of the data by the Tobit model, using the squared correlation between the observed and predicted dependent variable, is 54%. An OLS regression achieves an R^2 of 55%. Since the goodness of fit metrics are close, someone could be tempted to draw the conclusion that the data may be represented using an OLS regression. However, since the data associated to the RPS target corresponds to a corner solution response, a simple OLS regression is not a valid model because it would yield negative predictions and biased coefficient estimates. Therefore, only the Tobit model yields a valid representation for the data.

It was mentioned that the analysis conducted here is similar to the one presented in Huang *et al.* (2007) who consider socioeconomic, political, and environmental factors impacting on the adoption of an RPS by a state. In this thesis the explanatory variables considered are also socioeconomic, political, and environmental; however, the specific variables employed here are not the same as those used by Huang *et al.*. Huang *et al.* employed the following variables: the gross state product, the growth rate population, the level of education, the political party dominance, the expenditure on natural resources and the share of use coal in electricity generation. Comparing the variables among the two studies, it can be noted that the gross state product is similar to an explanatory variable used here: the GDP per capita. Given that similarity, one can compare the effect of such variables on the adoption of an RPS by a state. It turns out that both studies reach the same conclusion: the effect of the GDP and the gross state product is positive on the adoption of an RPS by state. This reinforces the idea that states with larger GDP will be more concerned about the environment and the use of renewable energy in electricity generation.

In Huang *et al.*'s work, the variable level of education is positive and significant. In this thesis the variable *gdpcapita*, which represents the GDP per capita, can be associated with an indirect representation of the level of education. In both studies these variables are significant and positive, thereby reinforcing the conclusion that a state having a population with high level of income is more concerned about environmental problems, and as a consequence, will be more likely to adopt an RPS policy.

The variables growth rate population, expenditure on natural resources, share of use coal in electricity generation, and political party dominance used in Huang *et al.*'s work cannot be directly compared with the variables used in this thesis. In spite of this fact, some conclusions will be drawn here for variables that are roughly similar. In Huang's work the political variable *PPD* is significant and negative, meaning that the states with a republican party dominance are less likely to adopt an RPS policy. On the contrary, the results of this thesis show that the political variable *govd* is not significant in the adoption of an RPS by a state. Moreover, the political variable *henvscore* is significant and positive. This means that states with representatives approving a high percentage of environmental laws, are more likely to adopt a state RPS policy regardless of their political tendency.

Finally, the environmental variable *coal* used in Huang's work represents the percentage of electricity generated using coal. This variable is not significant according to Huang's results. In contrast with this result, the environmental variable *perfossil* used here is significant and negative. This variable represents the percentage of electricity generated using any fossil fuel including coal. From this, states with high percentage of electricity generated using fossil fuels are less likely to adopt a RPS policy.

4.1.1 Future Work

In order to deal with the specification problems of the Tobit model, that is the lack of normality and homoskedasticity in the residual errors, other non-trivial models can be used. Among these models, the so-called hurdle or two-part models can be used when a Tobit model seem not to represent the data. In these models, both the probability and the expectation of the non-corner response values, conditional on the set of regressors, depend on different parameters. These parameters effect differently the regressors and the conditional probabilities and expectations (Wooldridge, 2006).

One of the goals of an RPS policy is to reduce the emissions of pollutants in the states where the policy is adopted. Several factors can play against this goal such as the REC market, geographical and technical conditions, among others. By means of a panel data analysis, using data from 1990 until 2006, one can test if the GHG have been successfully reduced during the years that an RPS policy has been executed in each state.

Chapter 5

Appendix

5.1 Test for Homoskedasticity in TOBIT Regression and Complete Results of the Test for Homoskedasticity in TOBIT Regression

Table 5.1: Test for Homoskedasticity in TOBIT Regression

Source	SS	df	MS	Number of obs	=	48
				F(24, 24)	=	1071.06
Model	47.9552	24	1.9981	$Prob > F$	=	0.0000
Residual	.04477	24	.0019	R-squared	=	**0.9991**
				Adj R-squared	=	0.9981
Total	48	48	1	Root MSE	=	.04319
one	Coef.	Std. Err.	t	$P > \|t\|$	[95% Conf.	Interval]
gres3	0.2794	0.0440	6.36	0	0.1887	0.3701
gres4	-0.4335	0.0193	-22.44	0	-0.4734	-0.3936
scoreperfossil	0.0459	0.0099	4.65	0	0.0255	0.0663
scoreperhydro	0.0462	0.0100	4.6	0	0.0255	0.0669
scoreperwind	0.0381	0.0168	2.26	0.033	0.0033	0.0728
scoreeast	0.0765	0.0589	1.3	0.206	-0.0451	0.1980
scorehenvscore	-0.0006	0.0014	-0.43	0.672	-0.0035	0.0023
scoregdpcapita	1.13E-06	6.31E-06	0.18	0.86	-0.0000	0.0000
scoreprice	-0.0025	0.0116	-0.21	0.832	-0.0264	0.0214

Table 5.1 – Continued on the next page

Table 5.1 – Continued from the previous page

one	Coef.	Std. Err.	t	$P > \|t\|$	[95% Conf.	Interval]
scoreno2	-0.0021	0.0007	-2.85	0.009	-0.0037	-0.0006
scoreso2	0.0004	0.0002	2.16	0.041	0.0000	0.0007
scoregovd	-0.0231	0.0376	-0.61	0.545	-0.1006	0.0545
score2perfossil	0.0201	0.0099	2.03	0.054	-0.0003	0.0404
score2perhydro	0.0199	0.0098	2.03	0.054	-0.0004	0.0402
score2perwind	(dropped)					
score2east	-0.0093	0.0311	-0.3	0.768	-0.0735	0.0549
score2henvscore	0.0003	0.0006	0.54	0.592	-0.0009	0.0015
score2gdpcapita	2.79E-06	2.65E-06	1.06	0.302	-2.67E-06	8.25E-06
score2price	(dropped)					
score2no2	-0.0003	0.0003	-0.9	0.376	-0.0008	0.0003
score2so2	0.0001	0.0001	0.74	0.464	-0.0001	0.0002
score2govd	-0.0382	0.0238	-1.61	0.121	-0.0873	0.0108
score2perfossil	(dropped)					
score2perhscore	(dropped)					
score2perwind	0.0376	0.0136	2.77	0.011	0.0096	0.0656
score2east	(dropped)					

Table 5.1 – Continued on the next page

Table 5.1 – Continued from the previous page

one	Coef.	Std. Err.	t	$P > \|t\|$	[95% Conf.	Interval]
score2henvscore	(dropped)					
score2gdpcapita	(dropped)					
score2price	-0.0033	0.0066	-0.49	0.626	-0.0169	0.0104
score2no2	(dropped)					
score2so2	(dropped)					
score2govd	(dropped)					
gres1	-4.5448	1.0538	-4.31	0	-6.7196	-2.3699
gres2	-1.7323	1.0188	-1.7	0.102	-3.8350	0.3705

display "$NR2 =$ "$e(N) * e(r2)$" with p-value = "$\chi 2tail(2, e(N) * e(r2))$

N $R2 = 47.9552$ with p-value $= 3.861 * 10^{-11}$

Bibliography

Christopher Baum. *An Introduction to Modern Econometrics Using Stata*. Stata Press, 1st edition, 2006.

A. Colin Cameron and Pravin Trivedi. *Microeconometrics Methods and Applications*. Cambridge Univeristy Press, 1st edition, 2005.

A. Colin Cameron and Pravin Trivedi. *Microeconometrics Using Stata*. Stata Press, 1st edition, 2009.

Cliff Chen, Ryan Wiser, Andrew Mills, and Mark Bolinger. Weighing the Cost and Benefits of State Renewables Portfolio Standards in the United States: A Comparative Ananalyis of State-level Policy Impact Projections. *Renewable and Sustainable Energy Reviews*, page doi:10.1016/j.rser.2008.01.005, 2008.

Christopher Cooper. A national renewable portfolio standard: Politically correct or just plain correct? *The Electricity Journal*, 21(5):9–17, 2008.

Karlynn Cory and Blair Swezey. Renewable Portfolio Standards in the States: Balancing Goals and Implementation Strategies. Technical Report NREL/TP-670-41409, National Renewable Energy Laboratory, December 2007.

EIA. The Changing Structure of the Electric Power Industry 2000: An Update. Technical Report DOE/EIA-5262(00), Energy Information Administration, October 2000.

Environmental Protection Agency. Clean Energy-Environment Guide to Action: Policies, Best Practices, and Action Steps for States. Technical Report, Environmental Protection Agency, April 2006.

Chris Harris. *Electricity Markets Pricing Structures and Economics*. John Wiley & Sons, Ltd., 2006. ISBN 9780470031827.

Ming-Yuang Huang, Janaki R.R. Alavalapati, Douglas R. Carter, and Matthew H. Langholtz. Is Choice of Renewable Portfolio Standard Random. *Energy Policy*, 35:5571–5575, 2007.

Mark Jaccard. *Encyclopedia of Energy*, volume 5. Amsterdam ; Boston : Elsevier Academic Press, c2004., 2004. ISBN 9780121764807.

Christopher R. Knittel. The Adoption of State Electricity Regulation: The Role of Interest Groups. *The Journal of Industrial Economics*, 54:201–222, 2006.

Frank Kreith and D. Yogi Goswami. *Handbook of Energy Efficiency and Renewables Energy*. CRC Press, Taylor & Francis Group, first edition, 2007. ISBN 978-0-8493-1730-9.

Ole Langniss and Ryan Wiser. Designing Effective Renewable Markets. *Energy Policy*, 31:527–535, 2003.

Hui Li, Hank C. Jenkins-Smith, Carol L. Silva, Robert P. Berrens, and Kerry G. Herron. Public Support for Reducing US Reliance on Fossil Fuels: Investigating Household Willingness-to-Pay for Energy Research and Development. *Ecological Economics*, doi:10.1016/j.ecolecon.2008.06.005, 2008.

Thomas P. Lyon and Haitao Yin. Why Do States Adopt Renewable Portfolio Standards?: An Empirical Investigation. *27^{th} Annual Eastern Conference*, 2008.

Barack Obama. Organizing for america. http://www.barackobama.com, last accessed (06/28/2009).

Karen Palmer and Dallas Burtraw. Cost-Effectiveness of Renewable Electricity Policies. *Energy Economics*, 27:873–894, 2005.

Barry G. Rabe. Race to the Top: The Expanding Role of U.S. State Renewable Portfolio Standards. Technical Report, Pew Center on Global Climate Change, June 2006.

Nancy Rader and Scott Hempling. The Renewable Portfolio Standard. A Practical Guide. Technical Report, National Association of Regulatory Utility Commissioners, February 2001.

Benjamin K. Sovacool. The Problem with the "Portfolio Approach" in American Energy Policy. *Policy Sci*, 41:245–261, 2008.

Ryan Wiser. Evaluating Experience with Renewables Portfolio Standards in the United States. Technical Report LBNL-54439, Ernest Orlando Lawrence Berkeley National Laboratory, March 2004.

Ryan Wiser and Galen Barbose. Renewable Portfolio Standard in the United States. A Status Report with Data Through 2007. Technical report, Lawrence Berkeley National Laboratory, April 2008.

Ryan Wiser, Kevin Porter, and Robert Grace. Evaluating Experience with Renewable Portfolio Standard in the United States. *Mitigation and Adaption Strategies for Global Change*, 10:237–263, 2005.

Ryan Wiser, Christopher Namovicz, Marck Gielecki, and Robert Smith. The Experience with Renewable Portfolio Standard in the United States. *The Electricity Journal*, 20:8–20, 2007.

Jeffrey M. Wooldridge. *Introductory Econometrics A Modern Approach.* Thomson South-Western, 3rd edition, 2006.