Solar Cities in Europe: a material semiotic analysis of innovation in urban photovoltaics

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Abstract

This thesis explores the gradual and by no means unproblematic emergence of solar photovoltaic technologies (PV) in European cities. It is a qualitative study of innovation in urban PV across three European cities: Barcelona (Spain), London (UK) and Paris (France) which draws on documentary evidence and interview data with a broad range of urban professionals engaged in implementing the technology. The thesis interrogates current understandings of how 'green' technologies such as PV are thought to bring about 'sustainable' transformations by 'breaking through' from the margins into mainstream society. Several innovation studies frameworks are assessed in terms of their merits and shortcomings for understanding innovation in urban PV. It is argued that extant literatures succinctly frame innovation as an interplay between that which is 'novel' and that which is 'in place', however, that they fail to address three issues that are critical for understanding how new technologies may emerge and transform: the multiplicity and heterogeneity of actors and their means for contesting 'sustainable' (or other) transformations, the complex spatio-temporality of 'barriers' to innovation, and the ways in which technologies gather humans, materials and spaces into new, potentially more 'sustainable' constellations. The thesis develops 'material semiotics' as a conceptual foundation and methodology for understanding innovation. Material semiotics provides powerful analytical sensibilities that enable the thesis to radically re-imagine the objects, processes and places involved in innovation. Through understanding innovation as characterised by attempts to bring forth into the present aspirations for alternative futures, urban PV is understood as simultaneously a vehicle for, as well as an outcome of, sustainable transformation. Its entanglement in a myriad of social, material, spatial and temporal relations is shown to engender a geography of 'sustainable' innovation that is much more partial and imperfect than current understandings suggest.

Main text overview

Peer-reviewed publications arising from this work

Maassen A. (2012) Heterogeneity of lock-in and the role of strategic technological interventions in urban infrastructural transformation. *European Planning Studies*, Taylor&Francis.

Maassen A. (2010) Planning urban energy trajectories: London and Barcelona. *Proceedings of ICE: Urban Design and Planning*, Volume 163, Issue 4, Pages 185-192, Institution of Civil Engineers, Thomas Telford.

Maassen A. (2009) Social science perspectives on energy and the case of urban PV. *Proceedings of ICE: Energy*, Volume 162, Issue 4, pages 161 –167, Institution of Civil Engineers, Thomas Telford.

POSTnote on "Solar Electricity" (2011) Parliamentary Office of Science and Technology (POST). 7 Millbank, London, SW1P 3JA. http://www.parliament.uk/business/publications/post/.

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Abbreviations

ABF	Architectes des Bâtiments de France
ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie
AEB	Agència de l'Energia de Barcelona
ANT	Actor-network theory
ARENE IDF	Agence Régionale de l'Environnement et des Nouvelles Énergies en Ile-de France
ASIF	Asociación de Industria Fotovoltaica
BIS	Department for Business, Innovation and Skills
CABE	Commission for Architecture and the Built Environment
CAT	Centre for Alternative Technology
CAUE	Conseil d'Architecture, d'Urbanisme et de l'Environnement
CEN	Creative Environmental Networks
CFI	Centre des Formations Industrielles
CLER	Comité de Liaison Energies Renouvelables
CLG	Department for Communities and Local Government
CSP	Concentrated Solar Power
CSR	Corporate Social Responsibility
DECC	Department of Energy and Climate Change
DFT	Domestic Photovoltaic Field Trial
DoI	Diffusion of Innovation
DOM-TOM	Départements et Territoires d'Outre-mer
DTI	Department of Trade and Industry
EDF	Electricite de France
EDIF	Energies durables en Ile de France
EIE	Espaces Info Énergie
EPIA	European Photovoltaic Industry Association

EST	Energy Savings Trust
DEFRA	Department for Environment, Food and Rural Affairs
GHG	Greenhouse gases
GLA	Greater London Authority
IDAE	Instituto para la Diversificación y Ahorro de la Energía
IDEMU	Institut de l'Ecologie en Milieu Urbain
IEA	International Energy Agency
IEA-PVPS	IEA Photovoltaic Power Systems Programme
JRC	EU Joint Research Centre
LCBP	Low Carbon Buildings Programme
LCCA	London Climate Change Agency
LS-BIPV FT	Large Scale Building-Integrated Photovoltaics Field Trials
MDP	Major PV Demonstration Programme
ODPM	Office of the Deputy Prime Minister
OECD	Organisation for Economic Co-operation and Development
OFGEM	Office of the Gas and Electricity Markets) OFGEM (Office of the Gas and Electricity Markets
OHLM	Office d'Habitation à Loyer Modéré
PASU	Pôle Accueil et Service a l'Usager, Direction de l'Urbanisme
PLU	Plan Local d'Urbanisme
PMEB	Pla de Millora Energètica de Barcelona
PV	Photovoltaics
REA	Renewable Energy Association
RO	Renewables Obligation
SEMAEST	Société d'Economie Mixte d'Aménagement de l'Est de Paris
SNM/MLP	Strategic Niche Management/Multi-level Perspective
SER	Syndicat des Énergies Renouvelables
STA	Solar Trade Association
STS	Science and Technology Studies
TIS	Technological Innovation Systems
UKBCSE	UK Business Council for Sustainable Energy
UN	United Nations
ZAC	Zone d'Aménagement Concerté

1 From space to earth... to the city?

The title of this thesis indicates three main areas of interest: photovoltaic technology (PV), which enables the generation of electricity from the sun's energy; innovation, a term that indicates progressive change; and European cities, suggesting a focus on particular geographical spaces as the arena for innovation in photovoltaic technology. Bringing these together frames the overarching concern of this thesis as the processes by which a technology such as PV emerges and becomes used more widely in particular spaces. Focusing on cities as sites of inquiry is significant with respect to historian Perlin's (2000) observation that the evolution of photovoltaic technology occurred 'from space to earth': first used to power satellites' radio transmissions to earth, nowadays PV is well-established in a range of terrestrial applications, such as low-performance electric consumer goods (e.g. calculators, watches, and radios (SANDAG 2005)) and catering for 'off-grid' electric needs (such as oil rigs, emergency call boxes and remote rural settlements). While these relatively well-established applications are mostly beyond the immediate reach of conventional electricity grids, using PV in cities implies 'solarising the electrified' (Perlin 2000) with a technology that is still relatively more expensive than conventional electrification using long-distance transmission lines. Cities are the historical birthplace of electricity grids and constitute perhaps the most 'grid-connected' places on earth, at least in the European context. However, despite comparing unfavourably to conventional electricity in terms of price, the application of PV in the built environment is receiving growing attention; owing to, on the one hand, the 'green', 'clean' or 'low carbon' quality of PV electricity, and on the other hand, its structural flexibility (see Figure 1.1) which makes it a technology that is relatively well-suited for integration into the urban built environment. While on the surface it would therefore seem that there is certainly a place for PV in cities, urban applications of PV have been relatively slow to proliferate. In this light, the thesis is concerned with exploring the challenges and opportunities for innovation in urban photovoltaics. Specifically, the thesis is guided by the following research questions:

1. What is the evidence of the emergence of PV in European cities?
2. Is there evidence of variation across different urban and national contexts?
3. What factors have facilitated the development of urban PV?

4. What factors have impeded the development of urban PV?
5. What are the prospects for the future of urban PV?

With these questions in mind, the remainder of the chapter provides a more expansive introduction to the discovery, principles and historical evolution in photovoltaic technology. Subsequently, it draws out the three-fold original contribution of the approach taken in this thesis to researching innovation in urban PV and concludes by providing an outline of the thesis as a whole.

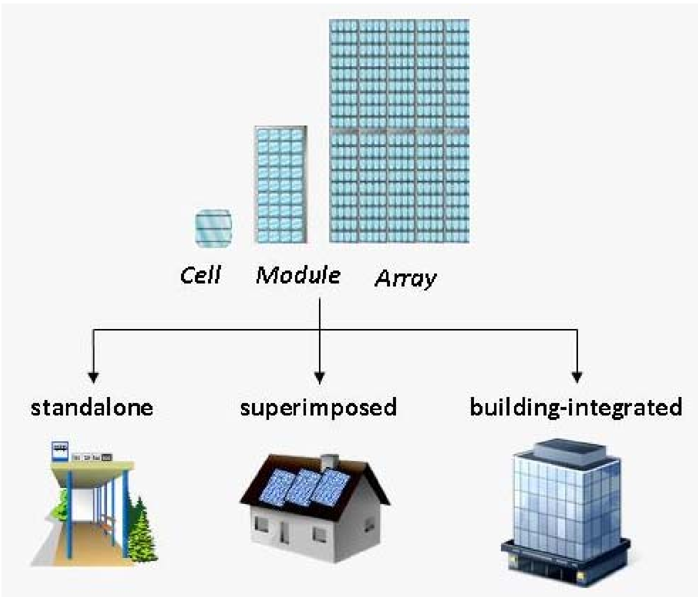


Figure 1.1 Modularity of PV systems
Cells, modules, arrays; and 'standalones', superimposed PV panels and building-integrated PVs
(Source: author's)

1.1 Discovery

The interest of two British scientists for what would later become known as 'photovoltaics' was aroused by an electrician's chance observation of the light-sensitive properties of the chemical element selenium while laying transatlantic telegraph cables in the 1860s. Through experimentation Professor Williams Grylls Adams and his student Richard Evans Day established that light causes a "flow of electricity" in this solid material – which they called "photoelectricity" (Adams and Day 1877; Perlin 2000: 17). This finding was thought to be "scientifically of the most far-reaching importance" (von Siemens 1885: 515, as cited by Perlin 2000: 18) by some of the most prominent scientists of the day, such as Werner von Siemens and James Clerk Maxwell. However, while recorded observations of photoelectricity in fact date back to as early as 1839[1], the phenomenon remained poorly understood until the early 20th century. In 1905 Albert Einstein published a paper[2] that theorised the laws governing the photoelectric effect. According to Perlin (2000: 20)

> Einstein's bold and novel description of light, combined with the discovery of the electron [in 1897[3]] and the ensuing rash of research into its behaviour, gave scientists in the second decade of the twentieth century a better understanding of photoelectricity… while nineteenth century experimenters called the process photoelectric, by the 1920s scientists referred to the phenomenon as the photovoltaic effect[[4]]. Solar cells then became a legitimate area for experimentation…

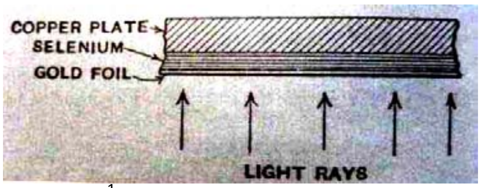
Only three years after the first coal-fired electricity power plant had been designed and built by Thomas Edison (in 1882), New Yorker Charles Fritts constructed the world's first photovoltaic cell (see Figure 1.2). This selenium module, which Fritts later sent to Werner von Siemens generated electrcity that was of "continuous, constant and of considerable force… not only by exposure to sunlight, but also to dim diffused daylight, and even to lamplight" (von Siemens 1885, as cited by Perlin 2000: 17).

1.2 Principles

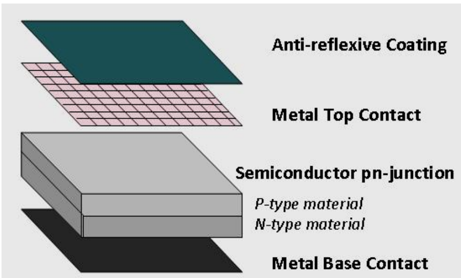
Put simply and briefly, the photovoltaic effect derives from the 'semi-conducting' properties of certain solid materials. The chemical makeup of semiconductors is such that when sunlight is incident upon them an internal electrical current is generated through the movement of electrons within the material. At the subatomic level semiconductors have electrical properties that are somewhere between that of conductors (such as metals) and insulators (such as rubber). When sunlight is incident upon a semiconducting material, current and voltage are generated, a combination that results in power. The smallest unit of semiconductor that is manufactured for

[1] Edmond Becquerel, a French experimental physicist, who could not explain the phenomenon.
[2] For which he was awarded the Nobel Prize in Physics in 1922.
[3] "The electron was discovered in 1897 and quickly won acceptance among physicists" (Pais 1982: 359; cited in Perlin 2000: 23)
[4] *Photos* is the Greek for 'light' and *voltaic* refers to the generation of electric current, after Alessandro Volta, inventor of the first electric battery.

solar power generation is called a ‘solar cell’. These are commonly distinguished according to three ‘generations’, which broadly refer to different types of semiconducting material. In first generation mono-crystalline silicon cells, which are employed in over 90 percent of existing installed PV systems worldwide, a relatively thick layer of silicon is laid over a metal backing (base contact). Second and third generation cells basically function the same way, however they use different types of (poly- and non-crystalline) silicon and a range and blend of other materials (such as Arsenide, Cadmium, Gallium, Selenium, Tellurium). The distinction between first and later cell generations is one of cost-performance: while the latter are cheaper to manufacture they tend to be less efficient than first generation cells. In all PV cells the two sides of the semiconductor are ‘doped’, meaning that impurities in the form of other chemical elements are added to the silicon. Doping is performed to improve the material’s conducting properties, by creating a natural electric field[5]. An anti-reflective coating and very fine metal grid is laid over the semiconductor, to which a wire and an electric application are attached, which close the circuit into an operable PV ‘system’.



Charles Fritt’s selenium solar cell[1]: “He spread a large, thin layer of selenium onto a metal place and covered it with a thin, semitransparent gold-leaf film”



A standard first generation mono-crystalline silicon cell[2]

Figure 1.2 Solar cells
(Source: [1]Perlin 2000: 17-18; [2]author’s)

[5] The ‘pn-junction’ (see Figure 1.2) consist of the following: one side of the semiconductor is enriched with electrons (n-type), by adding an element chemical element with a higher electron count (usually Phosphorous) to the silicon, and an element with a low electron count (usually Boron) is added to the other side (p-type).

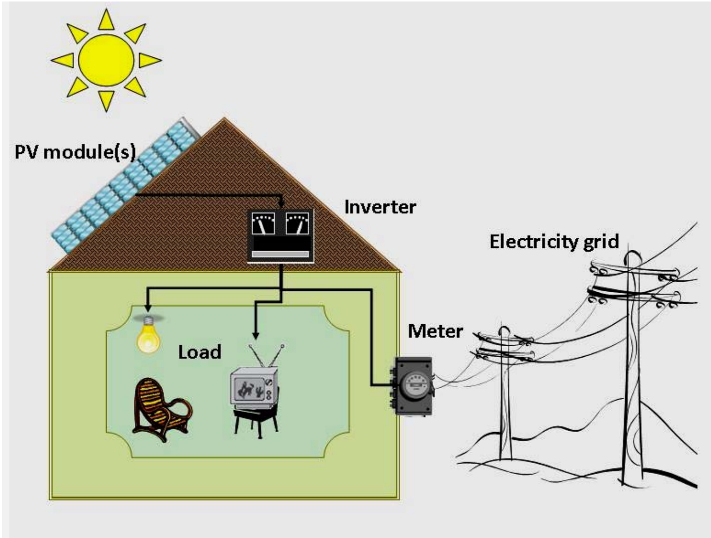
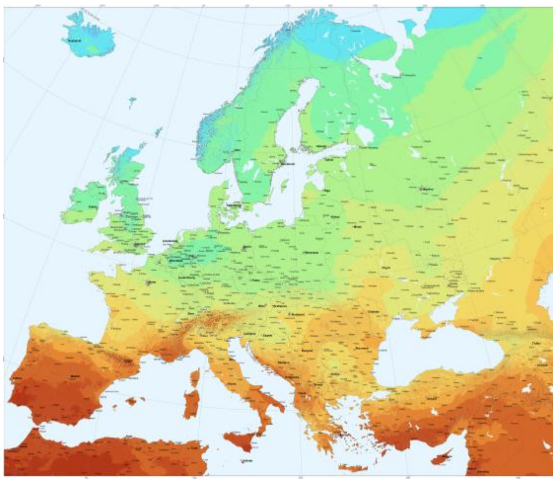


Figure 1.3 Basic PV system
PV module(s), inverter, electrical loads, meter and the electricity grid.
(Source: author's)

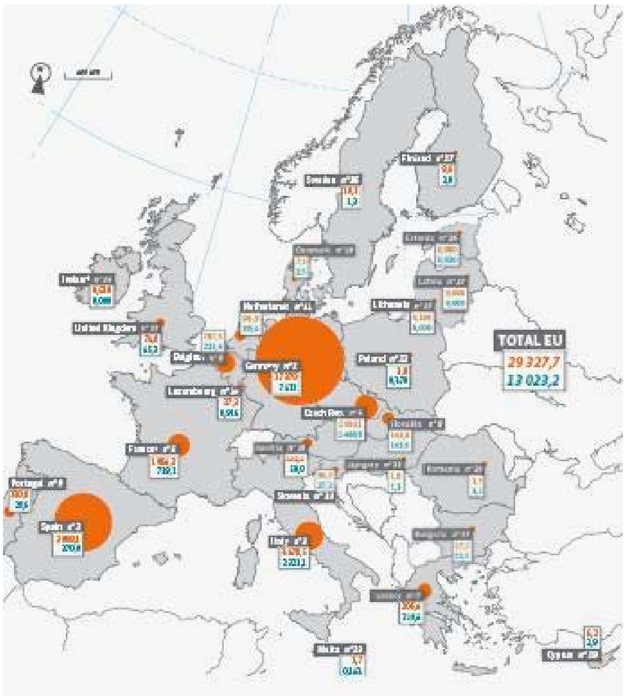
What all PV systems share in common regardless of semiconductor used is that they work through harnessing the electromagnetic radiation of the sun. Systems' capacity to generate power depends on the performance of electrical hardwares as well as cells' efficiency. The latter depends on cells' sensitivity to different parts of the solar spectrum. Currently, commercially available cells convert between 4% (third generation cells), 4-12% (second generation cells) and 13-22% (first generation cells) of sunlight that is incident upon them (EPIA 2011). While efficiencies depend on the properties of solar cells, the amount of available sunlight ultimately determines how much electricity is generated. The latter is a function of astronomical relationships (diurnal and seasonal cycles), atmospheric conditions (turbity and cloud cover) and topography (elevation and shading). This complex interplay is captured by radiation maps such as that reproduced in Figure 1.4 (PV-GIS 2007) which portrays the annual total radiation budget available on optimally situated PV systems in Europe. It is greatest with decreasing latitude. In European regions that receive relatively less radiation, such as the UK, it was found that a small-scale system (of approximately 13m^2 of PV panels or 1.6 kW_p[6]) on a suitable domestic roof generates about half of a domestic dwelling's electricity requirements averaged over one year (DTI 2006). Intuition might suggest that the use of

[6] The 'p' in kW_p stands for 'peak power'. This is a measure of a system's nominal electrical capacity. It is measured according to a set of 'standard testing conditions' (STC) which can be regarded as "optimal" conditions of irraditation, light intensity and temperature. In practice, however, PV systems frequently generate on average between 15 and 20% below peak power because of deviations from STC conditions.

PV would be greatest in regions of higher radiation, however, according to an authoritative PV market monitoring publication this is not the case (EurObserv'ER 2011). Rather, the geographically uneven development and implementation of PV is thought to be related to the technology's intimate relationship to national energy policy and the political imperatives of the times.



Global irradiation and solar electricity potential (optimally inclined PV modules)[1]



Photovoltaic power capacity installed in the European Union at the end of 2010[2]

Figure 1.4 European solar radiation map and total installed capacity 2010
(Sources: [1]Šúri et al. 2007 and [2]EurObserv'ER 2011)

1.3 Solar politics in the 20th century

The historical development of PV is tied up with the geopolitics of the twentieth century in terms of inter-state competition, economic development and emerging global ecological concerns. Until the mid-twentieth century early prototypes of solar cells had very low conversion efficiencies and were never commercialised, despite PV becoming an increasingly popular area of experimentation following Einstein's 1905 paper. It was not until the 1950s, in the midst of the Cold War 'space race' that practical applications for PV cells were found. In 1954 Bell Laboratories in the US experimented with the semiconducting properties of silicon and by 1958 the first low-performance PV cells were used in space on board the Vanguard I satellite to power its radio transmissions to earth. Nevertheless, according to Perlin, PV power's price – about forty times that of the price of retail electricity in the US in the 1970s (Perlin 2000) – restricted PV to extra-terrestrial applications. However, terrestrial applications for PV began to emerge for 'off-grid' electricity where solar electrification outweighed the costs of laying transmission lines connected to conventional power stations. Perhaps somewhat ironically, the first major purchaser of terrestrial PV was the US oil industry, which had both the funds and the need for off-grid electricity on its offshore oil platforms[7]. By the mid-1980s PV technology revolutionized telecommunications networks in remote areas worldwide, most notably in Australia (Mack and Lee 1989), solar water pumps were being used to combat drought in Africa, and off-grid PV systems were used to electrify rural areas of the developing world.

The importance of politics is brought further into focus considering that the expansion of the PV industry has taken place in the context of concerns over energy security and the ecological impacts of energy generation and consumption processes and practices. While the latter is a more recent phenomenon, the former date back to the 'energy crises' of the 1970s. During the decade and a half that followed hikes in global oil prices in 1976 and 1979 governments across the OECD channelled significant funds into PV research (Perlin 2000). The trend in Europe and the US was towards large and remote solar power stations, largely mimicking the existing blueprint of fossil fuel based power generation. However, several scientists and engineers observed that the technology does not exhibit the same economies of scale as are characteristic of conventional power plants and other (non-photovoltaic) solar technologies such as concentrated solar power

[7] Belonging to companies such as Amoco, Chevron, Exxon, Texaco and Shell (Perlin 2000).

(CSP)[8]. Decreases in oil prices in the 1980s are frequently associated with the drying up of governments' R&D funding for solar electricity in the 1980s (Berman and O'Connor 1996). The following decade, however, saw a revival of public policy interest in solar power across OECD countries. While PV continued to be framed as contributing towards a more diverse (and thus secure, less dependent) energy supply, the 1990s can be taken as heralding a more ecologically orientated framing of PV as a 'renewable' form of electricity generation.

While the 'green' credentials of renewable energy technologies such as PV had been the focus of civil society groups already in the 1970s (e.g. the Alternative technology Movement, see Smith (2003)), over the last decade or so the environmental benefits of alternative energy technologies have become mainstreamed into national and international political discourses. Initially framed as a question of 'sustainability' (UN 1987; UN 1992a), 'climate change' has since become formally enshrined in multi-lateral agreements such as the Kyoto Protocol (UN 1998). Nowadays the growing popular and political acceptance of the scientific theory of human-induced climate change is perhaps the single most important driver behind political commitments to 'decarbonise' fossil fuel-based energy systems worldwide. This is thought necessary in order to avoid the adverse impacts associated with a changing climate. That fundamental transformations in the domain of energy are essential is becoming increasingly accepted in the popular imagination, policy communities and academic circles – however what such far-reaching change (sometimes termed 'transitions') entails and by what means it ought to be achieved is matter of much debate.

It is generally acknowledged that action is necessary at all scales, including the multi-lateral, the national and the local. In parallel to the relatively recent focus on energy in the context of climate change, several non-governmental and municipal actors have advocated a pivotal role for cities in mitigating and adapting to climate change (Climate Alliance/Klimabündnis; ICLEI; World Bank 2009; UN 2011). Given their scale and density, cities are places of high energy demand and greenhouse gas emissions, with a tendency to export the impacts of their resource intensity beyond the urban boundary. However, in the context of the 'global loop' character of greenhouse

[8] While the latter achieve economies of scale on each additional unit of power generated following an initial substantial sunk infrastructural investment, each additional square metre of solar panel generates exactly the same amount of power. CSP in contrast works by directing mirrors onto a central tower in which steam is generated that drives turbines. This requires a large amount of space and is only feasible in direct sunlight conditions; both features which make CSP inoperable in dense urban environments with climatically often overcast conditions.

gas emissions cities may in fact emerge as chief victims of climate change (ibid.; Hodson and Marvin 2009b). On the other hand, it has been noted that urban authorities benefit from proximity to the citizen, and often constitute a homogeneous decision-making entity, which is thought to simplify complex issues of planning and monitoring associated with climate and energy policies (Capello et al. 1999; Nijkamp and Pepping 1998). However, academic commentators from a 'first wave' of urban climate change governance studies have noted that cities' resource intensity and dependence on out of town supply are frequently at odds with the ambitions of municipal authorities (Collier 1997; Bulkeley and Betsill 2003; Bulkeley and Kern 2006). There is, nonetheless, evidence of numerous urban authorities, in Europe and beyond, conducting ambitious energy upgrades to the built environment, with political commitments often articulated in terms of aspirations to 'internalising' a proportion of energy supply within the administrative urban boundary (Bulkeley and Schroeder 2008; Hodson and Marvin 2009b; Haughton 1997). Examples of emerging – and often self-styled – 'eco-cities', such as German Freiburg and Austrian Gleisdorf draw attention to the role that technologies such as PV might play in terms of 'greening' urban systems of provision.

1.4 Approach and contributions

It is a central contention of this thesis that currently prevailing literatures on technology and sustainable innovation fall short of providing a convincing account of the relationship between the objects, processes and places of innovation. *Conceptually*, the thesis takes as its reference point the often combined approaches of 'Strategic Niche Management' and the 'Multi-level Perspective' (*SNM*/*MLP*), which are gaining popularity and acclaim beyond their immediate field of innovation studies. While these are not the only possible reference point, the questions they ask about innovation and technology are deemed as the most useful entry point to answering the research questions. However, over the course of the thesis, and in particular in Chapter 2, the *SNM*/*MLP* framework is critically interrogated with respect to some of its implicit assumptions. It is argued that *SNM*/*MLP* has difficulty in accounting for the multiplicity and heterogeneity of actors involved in innovative processes, in particular their diverse means and forms of innovative intervention; that it oversimplifies the complex geography of innovation; and neglects to inquire into the precise part that particular technologies have in both mediating and making contestable the directions of future 'sustainable' transformation. This is done from a theoretical position informed by a trans-disciplinary strand of scholarship that has been called 'material semiotics' (Law 2007), which is informed by actor-network theory (ANT) in science and technology studies and diverse contributions from sociology, human geography, and anthropology that fall under a broader banner of ‘post-ANT’. Significantly, material semiotics fundamentally challenges current understandings of the nature of technology and innovation, how innovation is thought to take place and what its impacts are. Through re-conceptualising several concepts that are key to the *SNM*/*MLP* framework (and innovation studies as a whole) the thesis makes central to an inquiry into innovation questions of materiality, space, and politics.

Material semiotics is as much a conceptual position as it is an overarching research methodology. However, while material semiotics provides general conceptual and methodological sensibilities the literature itself offers little guidance about designing the research, collecting and analysing data, and presenting findings. In this light the thesis develops its own interpretation of the implications of a material semiotic position for the study of innovation, drawing on a range on methodological literatures from across the social sciences. The *methodological* contribution, therefore, is the development of an original way of making operational a material semiotic strategy for researching innovation. This is set out at length in Chapter 3 and forms the basis for the analytical Chapters 4-6. In particular the thesis’ take on comparison departs from more conventional approaches. Rather than predefining in a prescriptive manner the units which are to serve as the basis for comparison, what is relevant for comparison largely emerges during the process of analysis itself. This analytical position draws on current debates in urban studies, and reflects academic critical commentary on the *SNM*/*MLP* approach. Throughout the thesis comparison is used an explicit strategy (McFarlane 2010) for drawing out contrasts, nuances, and equivalences across various ‘units’ rather than adhering to one of these for the entire thesis. The result is a free flowing account of innovation in urban photovoltaics that switches between empirical cases and actors, nations, cities and technologies in order to provide insights, beyond the bounded case, into the particular question that each chapter asks about innovation.

Empirically, the thesis constitutes an ambitious exploration of the problematic implementation of urban PV in three European cities: Barcelona (Spain), London (UK) and Paris (France). Taking an urban focus is an ‘unusual’ approach to innovation in technology in the sense that it is not how the majority of scholars, and practitioners and policymakers encountered over the course of the research tended to frame the topic and their activities. However, as evidenced throughout the thesis as a whole, all three groups (and in particular policymakers and practitioners across different cities) are evidently grappling with the challenges involved in delivering new technologies into existing environments and practices. In addition, innovation scholarship, as Chapter 2 illustrates, has a longstanding concern with understanding how innovation occurs, albeit not typically with sensitivity to geographical space. As such the subject matter is of interest to academic scholarship, public policy and practice, each of which are concerned in their different ways with better understanding how a technology such as PV might arrive in the city. There is empirical merit in taking such a relatively complex three way empirical focus. It required working across three different urban and national policy contexts, four different languages (English, French, Castilian Spanish and Catalan) and several different professional groups (such as architects, engineers, policy advisors, consultants, activists, intellectuals, and others) – which do not speak the same language, linguistically and technically. This was made possible by the use of material semiotics as conceptual and methodological framework, setting the conditions for a unique study of tracing innovation in urban PV in urban Europe.

1.5 Structure of thesis

Having introduced the thesis' research questions, the origins, principles and evolution of non-urban PV, and the broad approach and contributions of this thesis, the remainder of this chapter outlines the thesis' structure.

Chapter 2, the main conceptual chapter of the thesis, provides a critical assessment of different innovation studies literatures and develops an alternative approach to researching innovation in urban photovoltaics. It is argued that out of three well-established approaches – Diffusion of Innovations theory (DoI), Technological Innovation Systems (TIS) and the combined approaches of Strategic Niche Management and the Multi-level Perspective (*SNM*/*MLP*) – only the latter offers a useful entry point to answering the research questions. While the *SNM*/*MLP* literatures are found useful in terms of the kinds of questions they raise concerning the nature of innovation, they are critiqued for lacking analytical scope to account for the empirical complexity of the research. In particular, it is argued that they lack analytical scope to conceptualise the relationship between technology and the city, the politics and dynamics of urban transformation and the importance of geographical space. The chapter then argues in favour of radical shift in theoretical position. A 'material semiotic' conceptual foundation is set out, which combines actor-network theory (ANT) and a range of ANT-inspired 'post-ANT' scholarship. In contrast to the evolutionary human-centred approach of innovation studies frameworks, material semiotics revolves around notions of 'relationality', 'materiality' and 'performativity' and 'multiplicity'. From a material semiotic sensibility the chapter thoroughly re-conceptualises technology, processes of innovation and the potential transformational effects of innovation. These three themes are the focus of the three analysis chapters (Chapters 4-6). Based on material semiotics, the conceptual framework of the thesis proposes to understand the practice of innovation as involving attempts to spatialise aspirations about desirable future outcomes using technology as a relational 'technique' to gather actors, materials and spaces into particular configurations. As such innovation is cast as taking place in a diversity of sites and as involving a myriad of simultaneously social, material, spatial and temporal relations. The outcomes of innovation, as a result, are never accurate and perfect translations of aspirations into practice, but rather imperfect hybrid states in between that which is novel and that which is in already in place.

To operationalise a material semiotic conceptual position, **Chapter 3** explores the implications such a position has for research practice. The chapter describes the adoption of an 'ethico-onto-epistemological' (Barad 2007) methodological position. This is different from conventional reflexive positionalities which recognise the role of the researcher's person in influencing the course of the research. Rather, research practice itself is understood as a fundamentally political, ethical and 'ontological', that is a world-making activity. Following a description of this methodological position the chapter outlines how the research was conducted. Different stages are described in terms of what was done and the choices that were made; including the exploratory stage, the stage of case selection, several data collection stages, and four cycles of data analysis. The originality of the methodological approach is related mainly to data collection and data analysis. A detailed discussion describes the translation of material semiotic principles to empirical data collection and analysis. This involves, most notably, gathering data through tracing associations from the desktop and in situ (rather than more conventional sampling procedures) and several cycles of data analysis to do justice not only to emergent 'themes', but also to narrative chronology, the re-construction of events and means for generating comparative insights. Central to the approach developed is a concern with providing analytical scope for the materiality and multiplicity of technology, innovation and its effects through developing an approach to comparison that is both generative of as well as compatible with a material semiotic methodology.

Chapter 4, the first analysis chapter of the thesis, attends to a question that is central to the thesis as a whole: ‘what is urban photovoltaics?’. In a fundamental departure to how technologies are currently understood in innovation and urban transition studies, the chapter develops a three-fold answer to this question. PV, it is argued, is simultaneously a means (a ‘technique’) through which actors seek to bring about what they understand as desirable states of affairs, a product that is emergent from common, multiple and materially heterogeneous materials (a ‘sociomaterial architecture’), and a mode of intervening in the world through different forms of spatialising aspirations (‘innovative utopics’). A material semiotic sensitivity to questions of relationality, materiality, and performativity understands PV as ontologically multiple, enacted and put to ‘work’ in a variety of sites and practices of those seeking to innovate. This material semiotic analysis of urban photovoltaics effectively decentres prevailing understandings (in academic scholarship and the popular imagination) of technologies as objects with singular identities and purposes. Rather than understanding ‘urban PV’ using a purely geographic definition based on the physical location of artefacts, the chapter argues in favour of a more complex and layered account of technology, in which technology is a fundamentally political object and practice. The chapter explores innovation in urban PV *in general* as well as shedding light onto the *specifics* of each geographical context.

Chapter 5 concentrates on what are commonly known as ‘barriers’ to innovation. Recognising the pervasiveness of this framing, however wary of the dangers of reifying a ‘barriers discourse’, the chapter reclaims the notion of ‘regime’ from its usage in the *SNM/MLP* framework in innovation studies. Applied to conceptualising ‘barriers’, that is to understanding how what is ‘in place’ shapes the possibilities of innovation, regimes are cast as heterogeneous in their effects, spatially multiple and of different temporal extents. Rather than, as in *SNM/MLP*, presume regimes to form constellations of incumbent actors that are institutionally aligned around well-established technologies, the chapter provides a more nuanced account of regimes, which does not take for granted a particular quality, spatiality and temporality of ‘regimes’. Instead, it is argued that regimes are simultaneously formative of, as well as emergent from different actors’ diverse and particular ways of innovating. The chapter argues in favour of attending to this multiplicity in order to capture the qualitative heterogeneity of barriers to innovation, the multiple overlapping spatialities that produce these across different temporalities.

The final analysis chapter, **Chapter 6**, explores the *unfolding* transformative impact that PV is having in Barcelona, London and Paris. It rejects viewing technologies such as PV as simply 'greener' than, and thus somehow superior to, incumbent energy technologies. The chapter draws centrally on the notion of heterotopia, as developed by Hetherington (1997), to cast a number of specific urban sites as 'places of otherness'. These constitute spaces in which alternate relationships around energy come into being, as a diversity of actors' perform a number of sustainability-orientated interventions. While 'solar heterotopia' constitute sites in which 'sustainable' transformations become intelligible they are not however equivalent to 'niches' in the innovation studies literature. Contrary to sustainability niches, which may 'upscale' into more superior configurations of their own, heterotopia are in-between spaces of contingency and imperfection which are permanently suspended in an open-ended state of negotiation. This is because any one's attempts to bring about more sustainable realities necessarily run into other forces, whether it is those reproducing the 'status quo' or others seeking to convert alternative aspirations about the sustainable 'good'.

2 Literature review and conceptual framework

2.1 Introduction

The thesis takes as its starting point a lens of 'innovation' for conceptualising the ways in which photovoltaic technology is brought not only from 'space to earth' (Perlin 2000) but also to the city. Innovation studies is a broad and diverse field of scholarship that is defined by a shared concern with how, why and at what rate 'innovations' become normalised into new patterns of service provision, industrial processes and consumption practices (Rogers 1962; Smith et al. 2010; Markard and Truffer 2008). Smith et al. (2010: 435) situate the initial impetus for innovation studies as reaching back to critical responses to the 'Limits to Growth' report published by the 'Club of Rome', an international think tank based in Switzerland concerned with global problems relating to 'pathways of world development' (Meadows et al. 1972; www.clubofrome.org). A set of critical scholars argued that the Malthusian report's treatment of technology as an 'exogenous' variable underplayed its importance in mediating natural and human systems; and, thus, the importance of technological innovations for 'stretching' and 'redefining' the limits of social and economic growth in Western economies (Cole et al. 1973; Freeman 1979; both cited in Smith et al. 2010). This trend in favour of developing a better understanding of the implications of innovation in technology for society, according to Smith et al. (2010: 435), is characterised by "a process of linking broader analytical frameworks to successively larger problem framings". Accordingly, a semi-coherent field of innovation studies is thought to have evolved from a relatively narrow focus on economic growth to a more recent concern with 'sustainable development'. It is within this emergence of an environmentally-orientated innovation scholarship that this thesis is situated.

However, while taking its cue from existing literatures in innovation studies, this chapter develops 'material semiotics' as a conceptual foundation for this thesis. As will be seen, material semiotics is less a coherent theory rather than a loose collection of analytical concepts and sensibilities (Law 2007; Gad and Jensen 2010) that take shape at the intersection of approaches in sociology, geography, and anthropology in the actor-network theory (ANT) 'and after' (post-ANT) tradition.

For understanding questions of innovation and capturing the intricacies involved, material semiotics starts out from a concern that it shares with innovation studies: the potentially productive nature of the relationship between technology and society. Material semiotics, applied to the problem of innovation, thus fundamentally shares with existing innovation studies approaches the notion that innovation is a purposeful process, an activity in which the boundaries between novelty (i.e. technology) and what is already in place (the 'context') are being redefined. However, materials semiotics and conventional innovation studies provide rather different ways of conceptualising what it is that makes technologies 'radically' novel and existing contexts 'sticky' or resistant to efforts to change them. The merits of a material semiotic approach over other innovation studies frameworks will become evident, for instance in the way that material semiotics provides the means to broaden the scope of analysis beyond instances of orchestrated 'experimentation' with innovations, which tend to be the focus of a currently dominant strand of innovation studies scholarship.

A material semiotic understanding of the actors, places, processes and the very nature of innovation is discussed in the third part of the chapter. Innovation becomes understood not as a noun – referring to an idea, a product or a process – but rather as a 'spatial practice', a process, in which directed efforts are made to achieve aspired-to states of affairs. Based on ANT-inspired material semiotics, the framework consists of four concepts which are developed, described and made operational in order to theorise innovation in urban photovoltaics. Importantly, this forms the basis of the material semiotic research methodology in Chapter 3 and shapes the analysis and presentation of findings in Chapter s 4-6. Prior to outlining this thesis' original material semiotic framework, the relative merits and shortcomings for understanding innovation in urban photovoltaics of three main approaches in innovation studies are assessed – Diffusion of Innovation (*DoI*), Technological Innovation Systems (*TIS*), Strategic Niche Management (*SNM*) and the Multi-level Perspective (*MLP*). While in particular the combination of the latter (*SNM*/*MLP*) is deemed as providing valuable contributions, three significant limitations of the *SNM*/*MLP* analytical framework are drawn out as problematic for the research. Specifically, based on the thesis' focus on multiple urban research sites, heterogeneous actors and groups and fast-paced processes of unfolding change, greater analytical sensitivity to questions of materiality, space, and politics is necessary. These thematic orientations are explored in the second part of the chapter, which draws out several issues and contributions, from a broad body of urban technology scholarship, on the relationship between technology and the city, the politics of urban technology and place-specific processes of urban technological change. Rather than conducting a synthesis to bridge the at times significant epistemological and ontological diversity characteristic of different approaches to urban technology, the chapter incorporates what are deemed their most important insights, in the context of this thesis, into an original conceptual framework using a set of material semiotic concepts, in Section 2.5. They address the key concerns of innovation studies, are attuned to the issues raised by perspectives on urban technology, and crucially, based on the sophisticated analytical sensibilities of material semiotics, provide conceptual scope to account for the empirical complexity of the thesis.

2.2 Innovation studies approaches to innovation in PV

The following sections explore three main approaches in innovation studies that have each been used to understand innovation in photovoltaic technologies: approaches that focus on the *individual* (‘consumer’ or ‘user’), the innovation *system*, and two related evolutionary approaches, which understand innovation as an interplay between processes of ‘variation’ and ‘selection’. These three broad approaches roughly reflect Smith et al.’s (2010) categorisation of innovation studies in terms of broadening analysis from a focus on discrete ‘green’ product innovations to broader “sustainable innovation journeys” (Geels et al. 2008). Their respective merits and limitations are discussed in each case. Overall, it is argued that each raises important questions and contains promising elements for understanding innovation, however, none is either *claiming* to be able to conceptualise innovation in urban technology, and nor emerges as conceptually equipped for this purpose.

2.2.1 Individualistic approaches: ‘Diffusion of Innovation’

Rogers’ (1962) *Diffusion of Innovations* theory is often known as the ‘classical’ model of technological diffusion. To capture the rate at which technologies ‘diffuse’ in any given society, Rogers put forward the ‘S-curve’ of innovation adoption (Figure 2.1). The curve seeks to capture how technologies are gradually taken up by different categories of technology adopters. These, Rogers argued, are distinguished according to their perceptions of new technologies. Different perceptions about a technology’s features are thought to differently shape prospective adopters’ purchasing behaviours. According to the importance different people place on technological attributes, they belong to the mutually exclusive categories of ‘innovators’, ‘early adopters’, ‘early majority', 'late majority' and 'laggards', each have different perceptions of technologies' attributes. From an initial emphasis on purchasing decisions as cost-benefit calculations, it has been proposed purchasing behaviours are not purely rational, but intimately related to "implicit cultural and personal meanings" (Hobson 2003: 103) tied to consumption practices, such as technology 'users'' notions of comfort (Shove 2003).

With respect to PV, specifically, Kearstead (2006) finds that adopters' favourable perceptions of the technology's 'green' credentials have led 'innovators' and 'early adopters' to purchase PV systems; while Faiers and Neame (2006) find that negative consumer perceptions of solar technologies in terms of costs and aesthetics are the reason for the technology's slow diffusion amongst the early adopters and the early majority. While 'classical' *Diffusion of Innovation* itself says little about the impacts that technologies have upon consumption behaviours, Keirstead (2006) sought to uncover the impacts of adopting PV upon household electricity usage. Keirstead (2006) stresses the interaction of individuals with technology by pointing out, for instance, that PV generates clean electricity as well as potentially leading to changes in energy consumption behaviours. While the extent to which PV produces such a 'double dividend' effect is notoriously difficult to quantify (Keirstead 2006; Bergman and Jardine 2009), the notion that technologies such as PV impact beyond their pure electrical output is echoed by Dobbyn and Thomas's (2005) study of the effect of introducing energy microgeneration into the household on energy-related practices and Hobson's (2006) exploration of 'techno-ethics'.

On the whole, while individual-centred approaches to researching technology 'adoption' provide some insight into processes of technology innovation, they are rather limited through their focus on the individual. They are succinct in identifying that prospective consumers' perceptions and consumption practices *do* matter for both the financial and personal investment in a technology. However, the use of *ex post* categories of adopters raises conceptual challenges, for instance, for differentiating relatively speedy adopters (innovators and early majority) from the early majority, late majority or laggards (as the latter three are undifferentiated until they actually adopt the technology). For a study of PV at the urban scale individualistic approaches provide little scope to account for a diversity of types of PV applications (e.g. different types of systems on different types of buildings – see Section 1.1) and a diversity of adopters, which may be individual citizens but also corporate organisations. In addition, individualistic approaches frequently fall short of capturing how technological change does not take place in a vacuum, especially not in a highly institutionalised setting as is the case with innovations in the electricity sector. Purchasing decisions (of whichever type of system and consumer) need to be understood as part of wider systemic processes which link demand side cost-benefit calculations of (mostly 'rational') consumers to entrepreneurial marketing and distribution processes (Miller 2009). How technologies such as PV become available in the first place, as a result of innovative supply side activities is the theme of 'technological innovation systems' approaches.

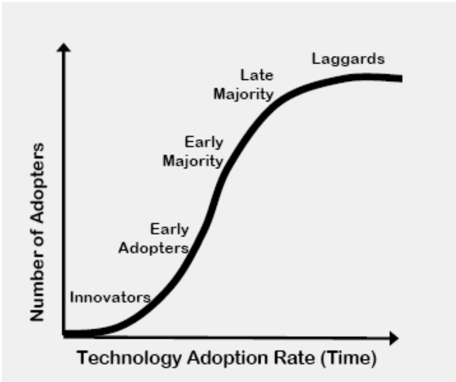
2.2.2 Systemic perspectives: Technological Innovation Systems (*TIS*)

For scholars of 'technological innovation systems' (*TIS*), the success of new technologies relates to the institutional and organisational well-functioning of technology-specific 'innovation systems'. Such *TIS* are understood as networks of actors which are promoting a particular technology under a shared institutional infrastructure (Carlsson and Stankiewicz 1991; Jacobsson and Bergek 2004; Praetorius et al.). Of particular interest for *TIS* scholars is to understand "general patterns shared by different innovation processes" (Markard and Truffer 2008: 596). These are thought to be related to the 'functions' of a *TIS*: "preconditions and dynamic features… of a successful technological innovation system" (Praetorius et al. 2010: 746), which are conducive to promoting (or hindering) the development of a specific technology. These patterns are theorised as mutually reinforcing alignments of technological and institutional factors which together produce (favourable) 'inducement' and (detrimental) 'blocking' mechanisms. The analytical focus is thus on the interactions between different networks of actors according to specific 'institutional' rules and codes of conduct, which may be formal structuring arrangements (markets, educational establishments and governments) as well as informal mediating influences, such as culture, values and norms (Jacobsson and Johnson 2000).

For instance, Jacobsson and Andersson's (2002) study of the German 'technological innovation system' for PV explains the success of the technology in Germany as a result of institutional (in particular Federal Government) support catalysed by the presence of influential industry networks, learning processes around resource requirements and technical experimentation, enabled by liberalisation processes in the electricity sector more generally. With reference to the UK, Praetorius et al. (2010: 752-3) argue that while political and public "'legitimation' is high in principle…. blocking mechanisms are strong, in particular in terms of institutional adjustments and political will"; the latter being in particular understood in terms of financial commitments. The *TIS* approach enables the authors to identify key players (e.g. the Micropower Council, the Renewable Energy Association and a high profile parliamentary group, PRASEG), and to provide an insightful comparison with Germany's experience (with 'microgeneration' rather than PV specifically, in this case). However, while the systemic 'institutional' *TIS* approach provides more scope to account for the complexity of technological change processes than individualistic perspectives, there are several factors that make it an unsuitable framework for the purpose of this thesis.

Perhaps most significantly, the approach has been criticised for being "myopic". (Markard and Truffer 2008: 611). Specifically, the definition of a *TIS* – comprising only those "actors, institutions and networks that are supportive to the innovation process" (ibid.) – downplays the significance of what lies beyond those supportive of the innovation. Because *TIS* approaches have tended to focus on the 'production' side (firms, trade unions, research establishments), usually little attention has focused on examining functional *TIS* dynamics on the user and application side. For instance, very little is said about the users that are prevalent in the individual-centred 'consumer' or 'user' approaches reviewed above. Further, Praetorius et al. (2010: 761) also acknowledge a "methodological ambiguity" of the approach. On the one hand, placing boundaries around a *TIS* is problematic, in particular from a comparative perspective: "a *TIS* may exist in one country within different system boundaries than in the other". It is rarely questioned that the *national* may not constitute the only or necessarily most appropriate unit of analysis. On the other hand, while the approach is thought to have generated a rich case-study based literature it has, however, up to date lacked conceptual theory-building concerning insights into the more precise dynamics that underlie a *TIS'* functional mechanisms (Geels 2010a; Markard and Truffer 2008; Coenen et al. 2009).

Owing to these significant drawbacks of the *TIS* approach, the following section considers the merits and limitations of 'evolutionary' approaches, which promise to provide an alternative to both the empirical and inward-looking shortcomings of the *TIS* approach and the narrow demand side focus on the individual in *DoI*.



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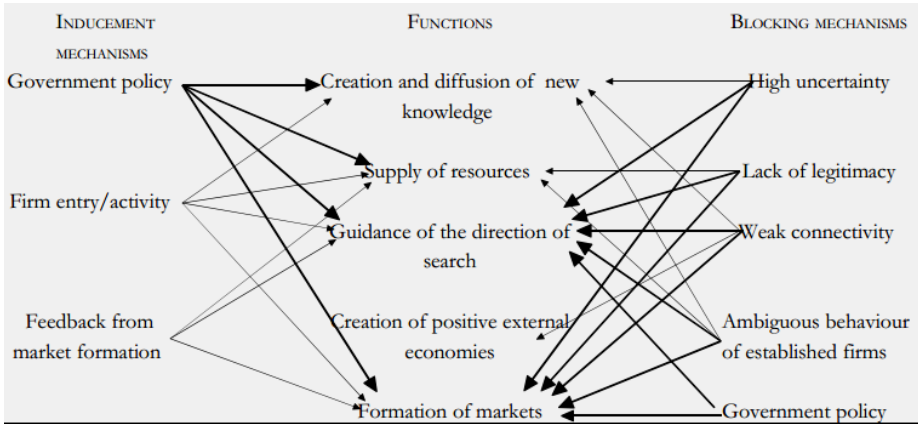

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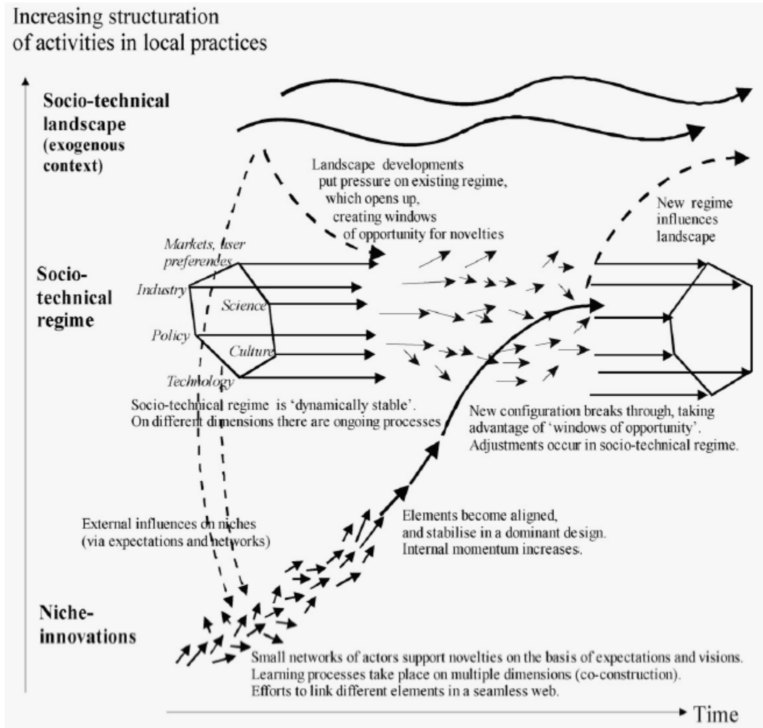

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Figure 2.1 Innovation studies frameworks: *DoI, TIS, SNM/MLP*
[1]Roger's (1962) 's-curve' of innovation adoption; [2]Inducement and blocking mechanisms affecting the TIS' function (Jacobsson and Bergek 2004); [3]Multi-level Perspective on systems in transition (Geels and Schot 2007)

2.2.3 Evolutionary approaches: *SNM* and *MLP*

'Strategic Niche Management' (*SNM*) and the 'Multi-level Perspective' (*MLP*) are two related strands of scholarship in innovation studies that can be understood as the latest broadening in problem and theoretical framing that Smith et al. (2010) diagnose in the evolution of the field. *SNM* and *MLP* were developed largely in parallel and are increasingly applied together in practice. This is possible because the frameworks are fundamentally compatible and complementary, based on their shared conceptual foundations in evolutionary economics and emphases on slightly different aspects of innovation.While *SNM* is concerned with processes by which potentially 'radical' technological alternatives 'grow' and 'stabilise', the *MLP* is more explicitly concerned with 'systemic' transformations. Here it is important to note that the notion of 'system' is used differently than in the *TIS* approach. 'Socio-technical systems' in *SNM*/*MLP* approaches refer not to innovative processes, but encompass all those elements which together mediate how "societal functions such as transportation, communication, housing, feeding are fulfilled" (Geels 2002: 1257). By focusing on transformations in socio-technical systems, *SNM*/*MLP* scholarship move away from focusing on individual 'green' technologies to a concern with the wider unsustainabilities affecting the various "systems of social and technical practice" (Smith et al. 2005: 1491). Rip and Kemp (1998: 361) draw out the distinction between 'discrete' and 'systemic' innovation, by comparing how "a Toyota and a Ford compete with each other, but cars as a system compete, for example, with railway systems". Importantly, beyond aiming to analyse technological innovation using a holistic multi-level framework, they also include considerations about the possibility to steer or 'manage' innovative processes.

Both approaches were originally developed by scholars based at universities in the Netherlands (in particular the Universities of Maastricht, Twente, Eindhoven and Utrecht), based on evolutionary economic arguments advanced by an earlier wave of innovation scholars (Kuhn 1962; Nelson and Winter 1982; Dosi 1982[9]). Since the 2000s the approaches have been generating a growing body of literature from beyond the traditional *SNM*/*MLP* research community, from fields of scholarship such as urban environmental governance (Bulkeley et al. 2011; Hodson and Marvin 2009a; Hodson and Marvin 2009a), economic geography (Truffer 2008; Coenen et al. 2009) and environmental sociology (Shove and Walker 2008; Shove and Walker 2010). This section reviews

[9] Existing 'technological paradigms' (shared problem solving routines) and 'technological regimes' (beliefs and expectations) among scientists and engineers condition innovative activities into 'trajectories'.

the ‘classical’ frameworks of *SNM* and *MLP* focusing on their analytical units as developed by scholars from within the immediate field. While *SNM* and *MLP* are increasingly becoming inseparable in practice, owing to their separate origins (in contemporary policy and historical studies, respectively) they are here discussed separately. However, following this separate review they will be referred to using the acronym ‘*SNM*/*MLP*’.

Strategic niche management

Central to the conceptual framework advanced by *SNM* scholars (Schot 1992;Schot and Rip 1997; Rip 1995; Schot 1998a; Schot 1998b) is the notion of ‘technological niche’, which is developed from the work of an earlier wave of evolutionary economic scholarship in innovation studies (Kuhn 1962; Nelson and Winter 1982; Dosi 1982). In such approaches, ‘market niches’ are understood as application domains for technologies that cater for consumer tastes outside of mainstream markets (Lynn et al. 1996; Raven 2007; Levinthal 1998). The difference between market niches and technological niches is that the latter are thought to lack even ‘niche’ markets, as they are fundamentally “mismatch[ed] with regard to existing infrastructure, user practices, regulations etc.” (Schot and Geels 2008: 539). The development of such ‘radical novelties’ (ibid.: 539) is much more challenging than in instances where niches cater for an existing user preference outside of the mainstream (Levinthal 1998), or innovation takes place through industry-led R&D (Van den Belt and Rip 1987). In *SNM*, ‘technological niches’ are thus understood as orchestrated spaces of ‘experimentation’ where different actors invest in underdeveloped technologies, fostering ‘hopeful monstrosities’ (Schot and Geels 2008: 539; Mokyr 1990) – that is, technologies which are potentially socially beneficial but are not at an advanced stage of development. The underlying assumption is that the orchestration of technological niches may function as a catalyst for the emergence of “‘proto-markets’ which may jumpstart the development of market niches” (Schot and Geels 2008: 539).

The concern of the *SNM* approach is understanding the processes by which individual experiments coalesce into technological niches, which may, eventually upscale into more stable ‘socio-technical’ configurations. *SNM* scholars have isolated three key processes to explain the emergence, growth and stabilisation of niches: the evolution of ‘expectations’, ‘network building’ and ‘learning’ processes. The first refers to the ‘socio-cognitive’ evolution of interpretations, visions and expectations of a technology of various actors (such as researchers, firms, users, interest groups and policy makers). The second is concerned with the growth of networks of actors around protected sites of experimentation, through for instance, private sector investment, experimental pilot projects, and government subsidies. Third, learning, about 'first-order' technical functionality and 'second-order' values and lifestyles, is thought to occur as a result of a diversity of actors engaging with the new technology in sheltered niche sites. It is thought that actors engage in experimentations on the basis of their expectations about a technology's potential, such as the promise of more sustainable energy systems in the case of renewable energy technologies. Crucially, as the name of the approach implies, *SNM* scholars are particularly interested in the possibility of strategically orchestrating niche development. Accordingly, experiments may be purposefully designed (for example by national governments) to bond previously unconnected actors into networks in which expectations converge around features such as a technology's future financial viability, ecological performance and cost-performance ratios more generally (e.g. Geels and Raven 2006), as a result of learning processes that have taken place in the niche.

While *SNM* has been influential as a 'policy tool' (Raven 2005) in the Netherlands, it has not had the effect of bringing about sustainable transitions: it did "not change the world in a direct, visible way… we were certainly over-optimistic about the potential of *SNM* as a tool for transition" (Hoogma et al. 2002: 196). For instance, with respect to PV Verbong et al. (2008) propose that the technology has 'failed' in the Netherlands. It is argued that this is a result of the technology not being adequately 'nurtured' and exposed too quickly to 'market pressures', despite benefitting from 'high expectations' and commitment from the Dutch government, the environmental movement and industry, and extensive 'learning processes' having taken place about the technology's benefits. Similarly, Verbong et al. (2008: 555) assess the 'failure' of several renewable energy technologies (wind, biomass, fuel cells/hydrogen, PV) as "characterised by many costly failures, setbacks, hype-disappointment cycles". For commentators such as Raven (2005), the failure of *SNM* to lead to technological niche stabilising and growing is related to the way in which attention has excessively focused on 'niche-internal' process (i.e. the processes of learning, network building and expectation articulation), at the cost of downplaying the importance of how what is already in place – the 'selection environment' – shapes niche actors' ability to innovate. It is in avoiding this myopic shortcoming (also characteristic of the *TIS* approach), that the *MLP* complements *SNM*'s focus on technological niches.

Multi-level Perspective on 'systems in transition' (MLP)

In the *MLP*, technological niches are located at the bottom of an analytical hierarchy of 'levels': niches, regimes, and landscapes are analytical constructs which are distinguished from another by ascending degrees of 'structuration'. This Giddensian (Giddens 1984) notion is used to cast actors' ability to innovate as dependent on the constraints posed by the 'selection environment', such as the presence of established technologies and infrastructures, interests, cultural values and consumption practices. In this context landscapes are characterised by long term "aggregated trends (e.g. changes in GDP, emerging environmental awareness) or sudden events (e.g. wars, sudden increase in oil prices, environmental disasters)" (Raven 2005: 33), which are conceived as external to individual agency. Niches and regimes are both made up of 'actors', technological 'artefacts' and 'rules', however they differ in 'structuration' (Geels 2004). The notion of 'rules' refers to "structures, which are recursively reproduced" (Geels and Schot 2007: 415). Rules are thought to structure and coordinate activities within and across particular communities of practice through common problem definitions, norms, collective histories, but also "social sanctions and networks of control" (Geels 2004: 904). 'Socio-technical regimes' are path-dependent as it is "difficult to change one rule, without altering others" (Geels 2004: 904), owing to the socio-institutional and techno-economic meta-coordination of rules are shared between different social groups[10]. Niches, in contrast, are weakly 'structured' by rules. This means that novelty that emerges in niches may find it difficult to 'grow' and 'stabilise' in face of landscapes and aligned socio-technical regimes. The *MLP* thus provides a more layered understanding of the selection environment than in *SNM* by suggesting that 'regimes' are the 'context' within which new application spaces must be created for the new technology.

From an original application to predominantly historical longitudinal studies, from which scholars such as Geels (2010) claim it was 'developed' and 'tested', the *MLP* is increasingly being applied as a complement to *SNM* in studying contemporary sustainability-related transformations. Originally, *MLP* scholars were particularly interested in phenomenon they term historical 'transitions', which are understood as "major transformations" in "societal functions" (Geels 2005c: 681). The notion of 'transitions' was developed through a series of historical case studies in areas such as (amongst

[10] For example, to incorporate coordination between groups of scientists and engineers pre-dating any particular innovative activities, the notion of 'technological regime' is used to refer to the "stabilised interdependencies" (Rip and Kemp 1998: 338) that unite these communities of innovation practice under "a core technological framework" (Kemp 1994: 1026).

others) lighting and marine mobility (which have been called transitions from 'gas light to electric light' (Schot 1998b) and from 'sail to steam ships' (Geels 2002)). *MLP* scholars argue that socio-technical transitions are realised at the intersection of parallel and linked-up processes between the levels of landscapes, regimes, and niches. For instance, a transition may occur, when under landscape 'pressures', regimes fail to remain coherent, which provides the opportunity for radical niche novelty to 'break through' and to consolidate into a new regime of its own (Geels 2007). From a historical focus the notion of technological transition has been reframed more recently to capture contemporary 'sustainability transitions' (Grin et al. 2010). The 'sustainable' adjective indicates a specific concern with normative goals of transformations, such as "deep cuts in greenhouse gases, step change improvements in resource efficiency, delivering the Millennium Development Goals" (Smith et al. 2010: 441). It is in the *MLP*'s transposition to contemporary normatively driven 'transition management' (*SNM*-inspired public policy intervention) that *SNM* and the *MLP* can understood as converging into '*SNM*/*MLP*' (Kemp and Loorbach 2006; Rotmans et al. 2001; Smith et al. 2005).

2.2.4 Limitations

It is important to note at this stage that *SNM/MLP* would not claim that the combined frameworks of SNM/MLP are specifically suited to an urban analysis of technology (e.g. Geels 2010). And, while the *SNM*/*MLP* framework was eventually rejected as the conceptual foundation for this thesis, it is worth stating the reasons for which the *SNM*/*MLP* framework had intuitive appeal. This derived from the framework's ambition to theorise complex socio-technical change processes, which established it as a prime contender for this thesis – at least at first glance. Three reasons in particular are mentioned in this section, before proceding to outline some of SNM/MLP's most important conceptual and methodological limitations.

Firstly, the approach is interested in the relationship between individual technologies and broader processes of "socially desirable" (Schot and Geels 2008: 539) transformations. This is compatible with the thesis' framing of innovation in urban PV as taking place against the background of concerns over climate change, economic growth and global concerns over energy security. Secondly, more than any other approaches in innovation studies, *SNM*/*MLP* is concerned with understanding innovation as an interplay between 'novelty' (in technological niches) and 'normalcy' (of socio-technical regimes). From this perspective, casting the application of PV in cities as a green 'niche' is compelling. Critically, PV's global evolution is frequently cast as the extension over time of technological applications from space to remote terrestrial applications (such as on oil platforms, in coastal areas, the railroads and telecommunications networks); which would imply an interpretation of the 'urbanisation' of PV as yet another 'branching' of the PV niche. Thirdly, *SNM/MLP* understands innovation as marked by purposeful interventions on behalf of innovators seeking to steer and 'govern' sustainable transformation. This again strongly resonates with the concerns that are at the heart of the research. However, as the remainder of this section illustrates, there are important limitations to the existing approach. These concern, for instance, the possibility of imposing the relatively smooth conceptual imaginary of 'analytical levels' upon the complexity of innovation in practice; how considerations of politics and space feature in the framework; and its (in)ability to evidence *unfolding* change, as opposed to diagnosing 'transitions' from a retrospective perspective. These three points are discussed in turn below.

In the first instance, a general point of contention in the literature has been with respect to the possibility of straightforwardly separating the analytical concepts of 'niche' and 'regime' in research practice (Bulkeley et al. 2011; Genus and Coles 2008; Rohracher 2008; Smith 2007). In *SNM/MLP*, niches and regimes are both made up of human actors and material artefacts whose relationship is defined according to a set of cognitive, regulatory and normative rule systems (Geels 2004; Geels and Schot 2007: 402). It is thought that different niche and regime activities can be identified through exploring the different degrees of 'structuration' of niche and regime sets of rules. However, in a review of several studies in the *SNM/MLP* tradition, Genus and Coles (2008) note a lack of explicit engagement with these 'rules and routines' that are thought to be central to inter- and intra-group coordination. Instead, the tendency has been to attribute certain actors as belonging to either the variation or selection environments[11]. However, that simply equating particular actors with either the niche-variation or regime-selection environments is problematic, is illustrated, for instance, by the case of 'low carbon' niche experiments in London (Bulkeley et al. forthcoming), which are orchestrated by the urban government, the Greater London Authority, and the utility *EDF* (both which could be cast as belonging to the dominant regime within the city). This suggests that separating between niches and regimes in practice is

[11] Verbong et al.(2008: 577), for instance, argue that it is possible to distinguish "actors from the variation environment (researchers, firms, technology developers) and selection environment (users, policy makers, special interest groups)".

much more difficult than *SNM*/*MLP* theory suggest; a task no doubt amplified when the empirical focus is a cross-urban and national study.

Secondly, thus, the difficulty of separating niches from regimes becomes particularly challenging in empirical cases that work across territorial and scalar governance relationships (Späth and Rohracher 2010;Bulkeley et al. forthcoming; Hodson and Marvin 2010). Several contributions from outside of the original *SNM*/*MLP* scholarship have served to de-stabilise the implicit spatialities of the *SNM*/*MLP* framework – a peculiar blend of *networks* of actors, operating (often implicitly) at the *territorial* scale of the nation[12]. In practice, it has been noted that actors at non-national scales of governance engage in technological innovation, such as urban (Bulkeley et al. 2010; Hodson and Marvin 2010), regional (Späth and Rohracher 2010) and 'grassroots' civil society (Seyfang and Smith 2006; Seyfang and Smith 2007) actors. Intimately related to this diversity of protagonists and spaces in practice is the need for greater sensitivity to the politics involved in change processes; in particular where such a diversity of actors is contesting the management of far-reaching change, as in the policy-orientated strand of the *SNM*/*MLP* termed 'transition management' (Shove and Walker 2008; Shove and Walker 2007). Such critical commentary concerning the sidelining of the interplay of spatial and political relationships in *SNM*/*MLP* is rather problematic for the present research. Understanding a largely 'global' technology, such as PV, in specific cities that are located in different European nation states, requires accommodating the geographical complexity as well as accounting for the diversity of actors engaged in promoting (or hindering) the technology's development.

A third point of criticism relates to the *SNM*/*MLP*'s inability to generate evidence of 'unfolding' transitions of contemporary (as opposed to historical, ex post) character. Even in historical cases (from which the notion of transition was developed) Genus and Coles (2008) note the difficulty of locating the start and end points of transitions[13]. Crucially, while it may be possible – arguably – to identify the point at which a transition has taken place in the past, the definition of 'transitions' as

[12] Smith et al. (2010) suggest this owes to the national public policy audiences of the theories' leading protagonists.

[13] While a transition in waste management (Geels and Schot 2005) is thought to have been achieved with the coming into force of new legislation ('rule change'), in the aircraft industry (Geels 2006; Geels 2005b) it is 'industry emergence' (infrastructure development, flights paths and companies) that defines the transition; in the case of the automobile (Hoogma et al. 2002) the parameter used is growing car ownership and infrastructural change.

"radically new ways of organising socio-technical provision" (Smith et al. 2010: 439) is an interpretation that is likely to be possible only in retrospective historical cases. Smith (2007: 447; original emphasis) finds that evidencing contemporary change is a much messier task, arguing that a "*spectrum* of practices" emerges (in the cases in eco-housing and organic food), rather than a clear cut niche-regime dynamic. The prevailing *SNM*/*MLP* vocabulary of transition through the 'accumulation' or 'upscaling' of technological niches is not attuned to the partiality of change evidenced by studies such as Smith's. In the context of a peculiar blend between 'historical successes' and 'contemporary failures' in transitions research[14] it emerges that what constitutes a 'transition' in practice is much less straightforward than in theory. The *SNM*/*MLP* framework's difficulty to evidence unfolding change is problematic in light of this thesis' research questions.

In sum, this thesis rejects using *SNM*/*MLP* as an analytical framework. While there is no doubt that the framework is ambitious in seeking to provide "a relatively straightforward way of ordering and simplifying the analysis of complex, large-scale structural transformations" (Smith et al. 2010: 442), the extent to which the model is analytical (as opposed to descriptive) is open to question. For instance, Genus and Coles (2008) note that across different *MLP* studies placing boundaries around niches and regimes is frequently poorly justified and largely at the analyst's discretion. While the SNM/MLP framework is very much 'alive' in the sense of undergoing constant evolution – development, refinement and redefinition through incorporating emerging criticisms – in the context of this thesis' particular empirical complexity, the model falls short of providing a sufficiently expansive analysis of what is involved in theorising innovation in urban technology. The 'analytical' units risk obscuring great diversity in both spatial and political terms in the way that (the mostly historical) cases of niche successes emphasise 'convergence' and 'upscaling' while failures are often blamed on poorly performing technologies or lacking commitment. However, through exploring a range of perspectives on urban technology, the following section suggests that an analysis of innovation in urban technology needs to be rather more attuned to the relationship between technology and the city, the politics of urban technology and the place-contingent factors shaping innovative processes. The discussion provides a link for moving towards the thesis'

[14] In contrast to historical 'success' stories, contemporary SNM scholarship tends to find that 'transition management' (SNM-inspired public policy intervention) has not had the effect of bringing about sustainable transitions: it did "not change the world in a direct, visible way… we were certainly over-optimistic about the potential of SNM as a tool for transition" (Verbong et al. 2008: 196). Similarly, the authors (2008: 555) assess the 'failure' of several renewable energy technologies (wind, biomass, fuel cells/hydrogen, PV) as "characterised by many costly failures, setbacks, hype-disappointment cycles".

conceptual foundations in material semiotics, which, it is claimed, accommodate the existing criticisms of *SNM/MLP*, urban technology studies' concerns while developing an original and conceptually sophisticated account of innovation.

2.3 Towards a conceptual framework: perspectives on urban technology

While not laying claim to providing such an explanation, fundamentally absent from the approaches reviewed in the previous section are considerations of the relationship between technology and the city. According to urban technology scholar Anique Hommels (2005) this is because innovation studies have not traditionally taken the city as a focus of inquiry. Better understanding the relationship between technology and the urban, however, is essential for answering the research questions of this thesis. This section thus explores some contributions from diverse approaches to studying technology and the city, from historical, urban geographical and urban political economy perspectives. The aim of this section is not to reduce the richness of these diverse intellectual traditions to their respective 'key' contributions or to compare and contrast these as fully coherent bodies of research. Instead, this section is organised thematically around three key issues relevant for this thesis specifically which are raised by different approaches to studying urban technology. The discussion below suggests that theorising urban technological change requires a more sophisticated understanding of the role of urban materialities, politics and geography. Having identified these themes, the chapter moves on to the conceptual framework of the thesis in sections 2.4 and 2.5.

2.3.1 Technology and the city

An important distinction between perspectives on urban technology and innovation studies is that the former are explicitly concerned with the relationship between technologies and their contexts. As opposed to a rather mechanical understanding of technology, as fulfilling 'social functions' as in *SNM*/*MLP* accounts (e.g. Geels 2002), from urban technology perspectives the very coherence and intelligibility of the city as a social, economic, cultural and political organisational unit is thoroughly tied up with its technologies (Bulkeley et al. 2010; Smith 2010; Hodson and Marvin 2010). For instance, features such as telephones, cars, residential, corporate and leisure facilities, buildings, sidewalks, public art, open spaces are part of the "complex materialities of the urban" that pervade the city (Latham and McCormack 2004: 703; Graham and Marvin 2001). While these are not different in kind from other technologies, what becomes known as urban 'infrastructure' is that which is "standardized, normalized and immanent" (Graham and Thrift 2007: 8; Star 1991). For instance, Graham and Marvin (2001: 21) note how

> turning a tap, flushing a toilet, or plugging in a power plug, are so woven into the fabric of daily life, and so 'normalised' and banal that (whilst they function adequately) they scarcely seem important.

Substantial parts of the urban technology literature is concerned with these quintessentially 'urban' technologies: urban infrastructural systems, the 'boring', mundane and largely 'invisible' technologies that "provide water and energy, remove sewage and trash, deliver information, and transport us between homes and workplaces" (Hård and Misa 2008: 8; Star 1999). Such infrastructural technologies are frequently understood as the 'material mediators between nature and the city' (Kaika and Swyngedouw 2000), the 'conduits' or 'sinews' which underpin "modern metropolitan economic and social life" (Graham and Guy 1995; Konvitz et al. 1990; Guy et al. 1996). Urban geographers Amin and Graham (1997: 417), for instance, note how urban technologies integrate the "multiple spaces, multiple times and multiple webs" of the city. Several historical studies have focused on the evolution of urban technologies, such as gas and electricity networks (Hughes 1983) and water supply (Swyngedouw 2006; Heynen et al. 2006; Gandy 2005). From a perspective that is sensitive to their importance for enabling urbanisation according to particular development logics, Gandy (2004: 373), for instance, notes how the "modern urban ideal" (Graham and Marvin 2001: 104) of universal service provision stood as "a powerful symbol for modernity in the wake of the chaotic and disconnected nineteenth-century city". However, this philosophy, Graham and Marvin (2001) argue, was eventually overtaken by processes of neo-liberalisation, leading to the 'splintering' of 'urban technical networks' (Coutard and Guy 2007: 718) and increasing degrees of urban inequality. Significantly, this intimate relationship between urban technology and political rationales underpinning different urbanisation logics alert us to the importance of the politics of urban technology.

2.3.2 The politics of urban technology

A recognition that urban technology is not void of politics is a second important difference between innovation studies frameworks such as *SNM*/*MLP* and urban technology scholarship. The latter does not assume that technologies have necessarily positive impacts upon their environments. Graham and Marvin's (2001) picture of "a relatively dark picture of ongoing trends which is largely dystopian" (Coutard and Guy 2007: 718) provides a strong contrast to interpretations of infrastructural change that see (in this case energy infrastructures) as the "key sectors for climate protection and the whole ecological modernization of societies" (Monstadt 2007: 327). Caution is particularly necessary in cases where normative ideals, such as that of the 'sustainable city', are mobilised (Gibbs and Jonas 2000; Whitehead 2003). Cautioning against uncritical and a- or 'post-political' (Swyngedouw 2009) managerial approaches to realising sustainability (as in *SNM*/*MLP* theory, according to Shove and Walker (2007)), critical urban scholarship draws attention to the "power relations and regulatory pressures within which sustainable cities are being forged… and who benefits most from these strategic formulations" (Whitehead 2003: 1192; Hodson and Marvin 2009a). Rather than a 'new' area of concern to urban governance, political aspirations of ecologically and socially 'sustainable cities' are cast as a particular way of reframing the management of urban areas (Gibbs and Jonas 2000: 355).

The significance of new technologies in these readings sensitive to the politics of urban technology is that they may constitute means through which different actors attempt to 'speak on behalf of the city' (Hodson and Marvin 2012) as a whole; at the risk of silencing more marginal voices. Graham and Marvin's (2001) 'splintering urbanism' thesis proposes that urban infrastructural innovation (in this case in information and communication technologies (ICTs)) are implicated in the de- and re-bundling of parts of the city into 'premium' spaces, while others are bypassed by these trends, partially disconnected or completely 'dumped'. Thus informed by Graham and Marvin's 'splintering urbanism' thesis, Coutard and Rutherford (Coutard and Rutherford 2010: 121-122; emphasis added) are wary of celebrating innovation in urban energy technology. Wary of positive and negative absolutes, they argue that the introduction of new energy technologies (such as PV) "*problematizes* the inherently networked nature of the urban". They note that ambivalent prospects of a 'post-networked city' made up of decentralised energy infrastructures; that these

> will not mechanically lead to 'utopian' sustainable cities that are more carbon neutral, more just, more liveable for all, but nor will they in themselves produce dystopian cities with socially and environmentally deprived areas next to secessionary green enclaves.

While the relationship between technology and the city is understood as a priori ambivalent (Coutard and Guy 2007), the impacts of new technologies upon urban relationships are thought to be socio-spatially uneven and heterogeneous.

For better or worse, urban technologies emerge as important nexuses around which urban futures are contested worldwide. In this context, a third theme in urban technology studies that is relevant for the present discussion relates to an important question concerning the study of technological 'urbanisms' – that is how one might go about studying *technologies* and *cities* 'in the plural'.

2.3.3 Technological *urbanisms*

Hommels (2005) proposes that there is an important geographical component to the dynamics of urban innovation, which she describes as "a laborious, time-consuming, and precarious process marked by the delicate interplay of a variety of social, technical, cultural, and economic factors" (Hommels 2005: 328). In a review paper on the 'undoing of urban obduracy', Hommels suggests that cities' resistance to innovative forces is strongly shaped by place-contingent urban configurations that precede new technologies. Calling for a geographically sensitive account of urban technological innovation, Misa and Hård (2008: 8) note that technologies do not "fall from the sky… Urban technological systems are creations of finance, regulation, and the prevailing political powers". In the introduction to their edited volume, *Urban Machinery: Inside Modern European Cities,* the authors (Misa and Hard 2008: 4) argue that, despite a certain tendency towards 'homogenisation' owing to 'translocal' flows of people, ideas, knowledge and engineering practices, "innumerable local and regional peculiarities have persisted across Europe"; citing as an example the functional similarity yet significant differences between the *métro* in Paris and the *tube* in London. Such studies in urban technology raise a fundamental question concerning the means by which technologies are made into urban phenomena particular to specific cities.

While Misa and Hard explore this question by comparing the local 'appropriation' of technologies that 'circulate' across cities, a recent revival of comparative urbanism (Ward 2010; McFarlane 2010; Robinson 2011; see Section 3.3) is wary of comparing cities as self-contained bounded wholes. Ward's (2010: 480) 'relational' comparative urbanism draws attention to how cities across the world are "implicated in each other's past, present and future". One crucial proposition has been to cease treating cities of the 'Global North' and 'Global South' as incommensurable and to capture the "persistently diverse but increasingly *interconnected* trajectories of sociospatial change in different parts of the world" (Hart 2004: 91, original emphasis; Robinson 2011). This is a compelling avenue of inquiry, which has not been pursued in relation to innovation in urban technology up to date. However, the emphasis on permeability as opposed to sealed territorial boundaries has important implications for how questions of geography, spatiality and connectivity more generally are approached in studying innovation. In relation to the intimate relationship between cities and their technologies and the inherently political nature of urban technology it suggests that a study of innovation in urban technology will require exploring how technology is constituted, as well as transcended, by the confines of 'city politics' (Ward 2010).

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To sum up, this section outlined three key issues that emerge across different strands of urban technology scholarship – concerning the intimate relationship, politics and geographical contingency of urban technology. This discussion served to provide the bridge for developing a conceptual framework for the thesis that is sensitive to these issues. Specifically, the choice to reject existing innovation studies frameworks is now fully justified in terms of its conceptual limitations (discussed in Section 2.2.4) and because considerations of geography, politics and the city are fundamentally absent from approaches such as *DoI*, *TIS*, and *SNM/MLP*. As discussed in this section, diverse perspectives on urban technology offer valuable thematic entry points to the study of innovation in urban photovoltaic technology. However, their intellectual diversity makes it difficult to integrate these into a conceptual framework. They have different intellectual origins, epistemologies and ontologies and more often than not raise and address rather different empirical questions. Instead of attempting to patch together a conceptual framework from the perspectives on urban technology explored in this section alone, Section 2.5 uses ANT and post-ANT material semiotic approaches to integrate the themes raised by perspectives on urban technology into a conceptual framework. Specifically, 'material semiotic' sensibilities are applied to the central questions of innovation – the role of technology, the relationship between novelty and normalcy and sustainable innovation as a normatively-driven process. It is argued that material semiotics provides the means by which criticisms of the *SNM/MLP* framework can be overcome and urban technology scholarships themes of materiality, space and politics can be accounted for analytically. The framework, outlined in the following section thus derives from taking innovation studies' analytical entry point (of conceptualising innovation as a dynamic relationship between novelty and normality) and devising a framework sensitive to questions of urban technology. In this way, the role of technologies in forging social, material and spatial relationships, more complex conceptions of geography and the need to account for a diversity of actors and sites of transformation are taken forward as central themes. In order to develop a material semiotics of innovation in urban technology the following section first provides an introduction to ANT and post-ANT material semiotics which will form the basis for rethinking current understandings of technology, the contexts, process and outcomes of innovation.

2.4 Actor-network theory and material semiotics

To understand what actor-network theory (ANT) and material semiotics has to offer to a study of innovation in urban technology, this section provide a brief overview of ANT's origins and its material semiotic 'diaspora' (Law 2007). This review is necessarily selective and does not claim to be representative of the nuances that characterise this ever-broadening and diverse field of inquiry. For more comprehensive reviews, see Law (1992), Latour (2005), Postma (2009), Gad and Jensen (2010) and Jensen (2004). The present emphasis is on five key analytical sensibilities that signal a fundamental departure from approaches such as the SNM/MLP framework: *material heterogeneity* and *non-essentialism*, here discussed together as they constitute the conceptual origins of ANT, signal an analytical concern with theorising the role of non-human entities and the nature of agency. Accordingly, entities – humans, non-humans – are understood as defined not by internal, essential qualities, but through networks of heterogeneous social and material relations. *Relationality*, *performativity* and *multiplicity*, are discussed under the broader banner of 'ANT beyond the network'. They indicate an ontological interest in the nature of reality and can be understood as constituting an extension (as opposed to an outright rejection) of earlier 'first wave' ANT. Relationality is used to indicate a broadening of classical ANT's analytical imaginary and repertoire of the 'network', while performativity and multiplicity suggest a theoretical orientation towards practice and complexity. Together, these five concepts are here taken as defining of a material semiotic intellectual strand of thought that is united less by empirical research objects or discipline rather than a common – ontological, epistemological and ethical – disposition (see also Section 3.2).

2.4.1 Origins: material heterogeneity and non-essentialism

The origins of actor-network theory (ANT) can be traced back to the late 1970s and early 1980s as an intellectual response to social constructivist studies of scientific practices of knowledge production (Bell 2003; Law 2007; Law and Mol 2001). In the context of a growing social science interest in issues of science and technology, mostly in Western Europe, a set of scholars (‘sociologists of science’) argued against the prevailing ‘naturalistic’ understanding of science; that is, of science as generating knowledge about an ‘external’ natural reality that exists independently from the social world. Contributions from scholars such as Bloor (1976), Latour and Woolgar (1979), and Pickering (1984) argued that the production of particular types, or ‘paradigms’, of scientific knowledge is the outcome of processes of social and political discursive construction, as opposed to being necessarily accurate representations of an external natural world. The proposition of sociologists of science was to analyse scientific claims and discourses ‘symmetrically’ (Bloor 1976), that is with impartiality to whether particular claims are inherently ‘true’ or ‘false’ statements about the natural world. Accordingly, the ‘constructed’ nature of scientific knowledge can be exposed through analysing instances of ‘scientific controversy’, during which competing claims about natural phenomena within or across different scientific communities are contested.

From sociologists’ of science arguments about the *socially* constructed character of scientific truths, ANT emerged as a ‘materialist’ response to science scholars’ focus on the purely discursive ‘closure’ of controversies (Law 2007). Early ANT studies were groundbreaking in their introduction of an analytical sensitivity to the ‘material heterogeneity’ of the ‘social’ world of science. For instance, Latour and Woolgar’s (1979) seminal laboratory ethnography argued that it is the highly material nature of scientific practices that enables the production of particular scientific claims in the first place. Through ethnographic studies of scientific practice, ‘science’ became understood as a thoroughly material undertaking. As Law (1992: 2) explains, science

> is the end product of a lot of hard work in which heterogeneous bits and pieces -- test tubes, reagents, organisms, skilled hands, scanning electron microscopes, radiation monitors, other scientists, articles, computer terminals, and all the rest -- that would like

> to make off on their own are juxtaposed into a patterned network which overcomes their resistance.

Through ethnographic (as opposed to purely discursive) methodologies that 'localised' science, ANT laboratory studies asked questions about *where* and *how* science takes place. This drew attention to the laborious character of science-in-action ("Labelling, marking, repeating, cleaning, numbering, noting, interpreting") – involving a myriad of (non-human) materials (Law and Mol 2001: 609). Only when all these heterogeneous elements are made to 'work' together in the laboratory, it becomes possible to take measurements from which representations can be abstracted and turned into scientific claims. Crucially, as observations and statements are turned into more material forms (graphs and figures, scientific texts, patents), their materiality allows them to circulate from the confines of the laboratory to distant locations, through the postal system, the internet, into scientific publications, patents, the media. In this account, the 'truth' of scientific claims is an achievement that is related to chains of 'translations' by which one scientist's inklings about "this blip on the graph" become converted into "the much harder statements about nature that circulate in scientific papers ('the figures in the table show …')" (Law 2007: unnumbered). For ANT theorists, thus, the success of science as a domain of the social is related to its materially heterogeneous 'networked' character, involving heterogeneous materials that have to hold together, and relying on communicative activities that link the immediate laboratory to other places, such as government offices, industry and other scientists' desks and laboratories.

From this sensitivity to the materiality of the social derived the radical methodological demand to extend science scholars' 'symmetry principle' (Bloor 1976), about truth and falsity of scientific claims, to the study of human and material worlds. This analytical extension was kindred to historian of technology Thomas Hughes' (1986; 1987) critique of determinist and reductionist analyses of technology. In a related manner to the emerging ANT scholarship, Hughes' study of the genesis of electric lighting in the US and Western Europe proposed that key individuals such as "Thomas Edison so thoroughly mixed matters commonly labelled 'economic', 'technical' and 'scientific' that his thoughts composed a seamless web" (Hughes 1986: 285). Hughes' 'seamless web' notion is useful for understanding the position that ANT scholars developed from their early laboratory studies. However, while Hughes (1986: 285) conclusion was that categories such as "technology, science, politics, economics and the social… should be used sparingly", ANT scholars drew more radical methodological implications from their studies. Specifically, the 'non-essentialist' position formulated by ANT scholars rejects the notion that a priori distinctions between 'social', 'technological' (or other) entities exist at all. This leads to a rejection of conventionally employed analytical categories along with their explanatory uses in favour of a higher level of abstraction: "heterogeneous elements" are described as acquiring attributes such as 'social', 'technical', 'economic' by virtue of entering into a priori "unspecified relationships" (Callon 1993: 263). The use of such abstract 'impartial' language is known as the principle of 'generalised symmetry' (Callon 1986b) by which the researcher uses a 'single repertoire' of analytical concepts for human and non-human entities.

The dual acknowledgement of material heterogeneity and non-essentialism has far-reaching implications for scholarly inquiry, as it fundamentally alters the basis from which explanation takes place. Just one example of many is Law's (1986 [2001]) application of material heterogeneity and non-essentialism to explaining the Portuguese marine expansion in the fifteenth and sixteenth century. Law argues that the expansion cannot be reduced to either "the technological, the economic, the political, the social, and the natural" (Law 1986 [2001]: 2). Rather than a pure 'technological' feat, the result of 'powerful monarchs' and 'clever' buying and selling strategies, for Law it is the juxtaposition into a network of the "the right documents, the right devices, the right people properly drilled" (ibid. 12) that enabled the Portuguese to significantly shift the power balance within Europe, and between Europe and the rest of the world. A fundamental explanatory shift take place in this account of marine expansion: sensitivity to the importance of materials in Law's account suggests that human agency is better thought of as a thoroughly *hybrid* phenomenon. Accordingly, the agency of the Portuguese – the king, merchants, sailors, astronomers, navigators – is inextricably tied up with small objects such as astronomical tables, astrolabes, vessels, ports and winds; such that 'the powerful' should be understood as 'effects 'of their actor-networks. The implication is that explaining a 'macro' phenomenon such as imperialism should be done through tracing it as an effect of the juxtaposition and interactions of the myriad of heterogeneous small-scale building blocks of 'the social' – i.e. relations between myriads of humans and non-humans.

2.4.2 Material semiotics: ANT beyond the network

Law (2007) uses the notion of material semiotics as an overarching descriptor for approaches originating in actor-network theory (ANT) and a 'diaspora' of scholarship across different intellectual traditions in science and technology studies, as well materialist feminism and some strands in sociology and human geography and organizational studies (e.g. Hinchliffe 2010; Mol 2002; Verran 2001; Hetherington 1997). The notion of 'diaspora', sometimes termed 'post-ANT' (Gad and Jensen 2010), is used to capture evolutions in ANT based on its different critiques. It increasingly applies to a broad and diverse body of scholarship converging around common analytical and methodological sensibilities. Significantly, this cross- and trans-disciplinary post-ANT body of scholarship has substantially expanded the concerns of 'first wave' ANT' to a much broader thematic issues, including traditional topics in Science and Technology Studies as well as, for instance health care (Mol 2002), natural resource management (Bear and Eden 2008) and education (Benjaminsen 2009). This has taken place in particular through orientations along three related methodological principles, which build on ANT's principles of non-essentialism and materialism – relationality, multiplicity and performativity. These are explored in turn in the remainder of this section.

Relationality

Crucially, building on ANT, post-ANT is better portrayed more broadly as a 'semiotics of materiality' (Law 2007: 4). As in ANT, this implies a focus on making sense of the world by focusing on relations *between* entities (as opposed to trying to understand these as self-contained wholes endowed with essential attributes). Specifically, a *material* semiotics applies the linguistic relationality of the semiotics of post-structuralist scholars (Greimas and Courtés 1979 [1993]; Serres 1974) "ruthlessly to all materials – and not just simply those that are linguistic" (Law 1999a: 4). Law, explains that ANT is based upon the view that

> terms, objects, entities, are formed in difference between one another. The argument is that they don't have essential attributes but instead achieve their significance in terms of their relations, relations of difference.
> (Law 2002b: 118)

The 'after' scholarship is marked in particular by a greater degree of concern with the conceptual limitations and implicit politics of 'network' accounts (Hetherington and Law 2000; Lee and Brown 1994; Strathern 1996; Star 1991; Singleton and Michael 1993). Specifically, it has been suggested that the spatial metaphor of the network naturalises a particular form of association at the expense of marginalising (or, 'othering') those which do not fit within a network imaginary. The 'first wave' of technoscientific ANT studies was accused, in particular by feminist scholars (Strathern 1996; Star 1991; Singleton 1998) as being of 'top-down' and 'managerial' character in its concern with accounts of the practices of the powerful actors' 'strategic aggrandisement', such as scientists (e.g. Louis Pasteur (Latour 1988) and imperialism (e.g. of the Portuguese (Law 1986 [2001]). Star (1991), for instance, asked about the different implications of ANT for a "male manager" and a "poor woman of colour" – which constitute two clearly very different cases of 'heterogeneous engineering' (Hetherington and Law 2000: 128). Anthropologist Marilyn Strahern (1996; Hetherington and Law 2000: 128-9) similarly draws attention to the "ontological and spatial fixity" of the actor-network, which understands relationality in terms of Western notions of connectivity (as 'kinship'), emphasising similarity and connectivity over, for instance, discontinuity and incoherence.

In a useful review of 'the consequences of post-ANT', Gad and Jensen (2010) argue that the broadening of ANT to other disciplines has generated fruitful new avenues for inquiry, including for instance a concern with non-networked forms of relationality and spatiality. The crux of this post-ANT development is a two-fold argument about the nature of reality. On the one hand, to elude the restrictive imaginary of the network novel forms of relationality are imagined by several scholars. De Laet and Mol (2000), for instance, argue that a particular technology, the 'Zimbabwe bush pump' is an object that is a product of a 'fluid' form of relationality. Rather than a network object, which would rely on more rigid relational associations, the "'fluidity' of the pump (of its boundaries, or of its working order, and of its maker)… is adaptable, flexible and responsive" (de Laet and Mol 2000: 225). The implication is that the pump's success is explained through discontinuity – fluidity – rather than the gradual blackboxing of relationships into standardised patterns. Similarly, Tironi (2009) provides the spatial metaphor of the 'gelleable' spatiality to explain how Santiago de Chile's music scene consists of the sporadic yet recursive assembling and re-assembling of musicians and their audiences in different urban spaces at varying times. Thus, the first point that derives from a more complex relational imaginary is that there may be a wide variety of ways in which heterogeneous entities relate and associate, beyond the network.

Multiplicity

On the other hand, allowing for greater relational diversity brings with it a focus of inquiry on the relationship between *multiple* forms of relationality. In this vein, Mol and Law (1994: 641) propose a 'social topology' approach, which develops a spatial answer to this question: the authors propose that "'the social' does not exist as a single spatial type, but rather performs itself in a recursive and topologically heterogeneous manner". Importantly, different forms of relationality are thought to perform 'the social' slightly differently and it is thought that through attending to this multiplicity better sense can be made of complex phenomena such as, for example, diseases (Law and Singleton 2003; Mol 2002), natural resource management (Bear and Eden 2008; Kortelainen 2010; Medd and Marvin 2008), the social and spatial organization of hospital wards (Middleton and Brown 2002; Moreira 2004), and car traffic (Kullman 2009). Medd and Marvin (2008: 297), for instance, use Mol and Law's (1994) topological notions of 'region', 'network' and 'fluid' to understand "the multiplicity of relations that differentiate as much as integrate the regional space" of water governance in the UK. Geographers Bear and Eden's (2008: 500) analysis of a fishery certification scheme similarly demonstrates the merits of a multi-topological approach to capture how the fluidity of the ocean and its fish frequently elude the Euclidean fixity of the mapping scheme. Here, for the authors "greater spatial sensitivity… leads to a deeper understanding of how the certifications work". An attention to such spatial multiplicity, one of the key features of post-ANT material semiotics, has yielded a number of thoughtful interventions, in particular coupled with performativity, the third key concern of material semiotic scholarship.

Performativity

The recognition that the relations that make 'the social' are heterogeneous and multiple marks the material semiotic turn to performativity, which is characterised by an analytical concern with 'practices'. As opposed to Butler's (1990) and Goffman's (1959) understanding of performativity applied to embodied performances of culture and identity, material semiotic scholarship is less concerned with developing a strict definition of what counts as 'practice' rather than working with the implication that the notion of performativity or 'enactment' has for 'metaphor and explanation' (Law 2007). Broadly speaking, practices are enactments of materially heterogeneous relations which “generate realities” (Law 2007: unnumbered). In some ways performativity is antithetical to earlier ANT’s focus on understanding the reproduction of technoscience, as considering the social as performed through a multiplicity of heterogeneous relations effectively decentres dominant accounts and ‘powerful’ voices which may make it seem as though reality is singular and coherent. Effectively, sensitivity to multiplicity and performativity shifts focus and means of explanation. For instance, health anthropologist Mol (2002) argues that the multiple reality of a particular disease in a specific Dutch hospital has important implications for which treatment options are offered to patients. Here, Mol’s concern is not with the ways in which different professionals attempt to construct “a sociotechnical network stronger than their competitors, and thereby gain a monopoly on defining [the disease]” (Gad and Jensen: 11) – as perhaps a more conventional ANT approach would. Instead, Mol’s concern is to explore the practices of surgeons, epidemiologists, nurses, and physiotherapists in terms of ‘what it means to treat’ from the perspective of patients’ wellbeing. Performativity thus introduces a dynamic and fractal conception reality. In Tironi’s (2009) case, a social topological study is used to challenge conventional accounts of ‘creative clusters’ in economic geography, making central to understanding Santiago de Chile’s alternative music scene its variable spatiality and temporality.

For the present purpose, performativity refers to the enacted nature of reality, implying focusing attention on the practices that constitute complex phenomena. It should also be noted that the shift in understanding reality as a singular construction to a socio-materially multiple performance is also – more often than not – accompanied by a self-reflexive focus on scholarships’ own politics in terms of producing particular academic accounts. As with Mol’s explicitly interventionist scholarly practice, the ‘ontological politics’ of this thesis, in particular the implications of methodological choices and its potential repercussions are explored in more depth in Chapter 3. At present the chapter turns to applying material semiotic sensibilities to the study of innovation in urban technology.

2.5 A material semiotics of innovation in urban technology

This section now develops a set of concepts into a framework for understanding innovation in urban photovoltaics from a material semiotic position as outlined in the previous section, according to lines of inquiry set up by innovation studies (see 2.2.4) and orientated along the themes raised by urban technology scholarship (see 2.3). Table 2-1 summarises the thesis’ framework's foundation in innovation studies, urban technology scholarship and material semiotics. Importantly, the conceptual exposition that follows builds on several aspects of existing approaches in innovation studies. At a basic level, innovation itself is understood in its literal meaning – from the Latin verb *innovare,* to 'renew or change' – as a phenomenon taking shape at the interface of efforts to generate novel arrangements in existing contexts. While questions of innovation are thus understood as fundamentally related to achievements of novelty, it is of concern to understand the achievements of a particular kind of novelties: desirable, favourable changes to the status quo. As a normatively driven, purposeful endeavour innovation is cast as involving the emergence and consolidation of favourable changes to the status quo. While in innovation studies this has been treated as an issue of normalising ('embedding', 'mainstreaming', 'standardising') particular 'innovations' – ideas, products, services – into society, material semiotic sensibilities, however, fundamentally shift how 'innovation' itself is conceptualised (and, as explored in Chapter 3, researched), how technology features in processes of innovation, and how transformations occur in the conditions of what is possible.

Table 2-1 Lines of inquiry, themes and analytical sensibilities of the conceptual framework

Lines of inquiry	Themes	Analytical sensibilities
Innovation studies	*Urban technology perspectives*	*Material semiotics*
(Section 2.2.4)	(Section 2.3)	(Section 2.4)
Relationship between technology and sustainable transformation	Relationship between technology and the city	Material heterogeneity Non-essentialism
Innovation as a dynamic interplay between novelty and normalcy	Politics of urban technology	Relationality Multiplicity
Innovation as involving purposeful intervention	Geography of urban transformation	Performativity

Rooting its conceptual foundations in material semiotics serves to indicate that this thesis draws in fundamental ways on ANT's principles of non-essentialism and materialism and is further informed by post-ANT theoretical orientations concerning relationality, multiplicity and performativity. However, less a fully coherent body of theory rather than a set of analytical 'tools' and 'sensibilities' (Law 2007; 2008a), material semiotics provides a general theoretical position rather than a fully fledged framework. In fact, material semiotic scholarship has not dealt with the topic of this thesis in any direct or explicit manner. In this context, what follows constitutes this thesis' original interpretation of the *implications* of material semiotics to understanding innovation in urban technology. It is important to note that the development of the framework outlined in this section emerged as a product of the research process itself. Material semiotic sensibilities provided the pivot around which a set of notions began to take shape as a consequence of engaging material semiotics with question of innovation. It was a sense of dissatisfaction with *SNM/MLP* concepts' failure to account for the empirical complexity encountered in practice (see further Chapter 3) that catalysed a thereafter relatively organic emergence of a range of concepts more suited for framing innovation in urban PV (implications of such an evolving 'theory-building' approach are considered in Section 3.6).

The framework set out in the remainder of the section and chapter is organised in four subsections, Sections 5.2.1-5.2.4, which introduce four related concepts that form the basis for conceptualising innovation in urban photovoltaics in this thesis around four themes: Technology, Innovation, Regimes and Transformation. These subsections are used to develop the conceptual implications that a material semiotic position has for theorising innovation in urban technology. Section 2.5.1 draws attention to the need to interrogate the ontological nature of technology prior to seeking to understand how technologies are achieved and the transformative impacts they may have. After developing a relational understanding of technology, Section 2.5.2 proceeds by rethinking the nature of innovative practice. It argues in favour of a more expansive understanding of what it means to innovate by considering innovative practice as utopian in character. Understood as a *process* (rather than referring to an object), a material semiotic analysis of innovation draws into focus the very processes through which the novel is itself constituted *in relation to* the normal. Thus taking the interdefinition of the novel and the normal as the starting point for an analysis of innovation, innovation becomes understood as consisting of attempts to make concrete desirable states of affairs. Efforts to innovate are, however, fraught with challenges in the context of relations that predate efforts to innovate. These challenges, or 'barriers', are outlined in Section 2.5.3 as becoming intelligible relationally, through the very act of innovating. Attuned to a technology's potentially non-coherent sociomaterial multiplicity and the interdefnition of the novel and the normal, Section 2.5.4 argues that spaces of alternative to the status quo, however contested and spatially complex, are engendered at the intersection of the novel and the normal in ways that are more subtle and diffuse than bounded niches 'accumulating' or entire regimes 'shifting'.

2.5.1 Technology

Material semiotics provides the basis for developing a fundamentally different understanding of the nature of technology as is currently present in innovation studies. In innovation studies technology tends to be understood in functional terms of fulfilling 'social functions' (Geels 2002; Rotmans et al. 2001). However, by drawing attention to technologies' potentially dystopian effects (Coutard and Guy 2007; Graham and Marvin 2001), urban scholars caution against such an a-political or even optimistic understanding of technology (e.g. as 'sustainability mediator' as in Monstadt 2009). Similarly, from a non-essentialist position it is rejected that technologies have a particular intrinsic function, as technologies are part of a broader set of sociomaterially hybrid relations. By arguing that entities' properties are not given in the object itself, a material semiotics inquiry enables a rather different analytical entry point. This shift is aptly formulated by philosopher of technology Button (1993) (although, it should be noted, not a material semiotic thinker himself). For Button, the shift in focus entails moving from treating technology as a "platform" for studying another phenomenon (e.g. sustainability, urban injustice) to interrogating "the constitution of 'technology' as a topic in its own right" (Button 1993: 10). In other words, prior to understanding the transformative impacts of technology, it is first necessary to interrogate what it is that makes particular objects 'technologies'.

Here material semiotics proposes to interrogate taken for granted understandings of technology present in more conventional constructivist approaches in technology studies, from which *SNM/MLP* draw inspiration. Specifically, in *SNM/MLP* it is thought that that different actors engage in niche experimentation based on their 'expectations' of a technology's future 'sustainability' potential. Within this understanding *SNM/MLP* scholars argue that different actors may have quite different expectations of the same technology. They call this the 'interpretatively flexibility' of technology (Pinch and Bijker 1984), a notion appropriated and re-interpreted from the 'social construction of technology' strand in science and technology studies – SCOT[15]). In *SNM/MLP*

[15] A careful engagement with SNM/MLP scholarship's appropriation of the notion of interpretative flexibility reveals a significant difference from its original meaning in SCOT. While both take it to refer to the potential different engagements of different actors with the same technology, in SCOT this leads scholars to focus on

interpretative flexibility is largely a result of there not being sufficient ‘stabilisation of rules’ in the niche (Geels 2004; Schot and Geels 2008). For instance, lacking cognitive consensus, some actors may pin high hopes on a technology such as PV, while others remain unconvinced of its performance (Verbong et al. 2008). If ‘niche-building’ processes are successful, over time, expectations may converge and rules ‘stabilise’. Interestingly, the notion of expectations ‘converging’ in *SNM/MLP* constitutes a rather more consensual picture than Pinch and Bijker’ conflictual account of inter-group negotiation. However, whether expectations converge or conflict, fundamentally at stake is an interest with the degree of ‘closure’ or increasing ‘structuration’ of novelty. This concern with ‘standardisation’, a well-established topic in innovation studies, is translated in *SNM/MLP* into implying that new technologies somehow lack standardisation or streamlining; in the absence of which they cannot ‘stabilise’ and ‘grow’.

However, from a material semiotic perspective the question of standardisation features rather differently because there are potentially numerous forms of relations that can yield a ‘success’; not just highly standardised ones, as the case of the ‘Zimbabwe Bush Pump’ is thought to illustrate (de Laet and Mol 2000). Achieving novelty, rather, is a question of *the quality of relations between heterogeneous elements*. As Law (1992: 2) explains, in material semiotics a question of innovation is about

> how some kinds of interactions more or less succeed in stabilising and reproducing themselves: how it is that they… become "macrosocial"; how it is that they seem to generate the effects such power, fame, size, scope or organisation with which we are all familiar.

the conflictual relationship *between* different social groups’ interpretations of a technology, while SNM/MLP theory focuses on the temporal evolution (and potential convergence) of expectations *across* different actor groups (Bijker, Hughes, and Pinch 1987; Bijker and Pinch 1984). While in both cases meanings of technology tend to narrow in meaning towards ‘closure’, in SNM/MLP this is taken to occur on the basis of temporally extensive learning processes (about ‘objective’ technological attributes), while in SCOT this is due to one social group imposing their definition of the technology upon others. As a consequence of these different notions of interpretative flexibility, SCOT’s central contribution to the study of technology, namely to challenge the notion that technology has a singular and straightforward trajectory that derives from stable and intrinsic technological attributes, is lost in SNM/MLP scholarship.

Concerning technology, this implies rethinking its role and that of its artefacts in processes of innovation. Specifically, it urges to interrogate assumptions about the nature of technology that are deeply embedded into constructivist accounts, which prevail in innovation studies.

These, it is argued, perform an unhelpful distinction between a technology's material 'form' and social 'function', which leads to an understanding of technology as giving rise to potentially multiple 'social' interpretations of an otherwise materially singular entity. In contrast, material semiotics rejects this 'duality of technology' (Orlikowski 1992; 2010; Kroes 2010) – of form and function. A relational account of technology understands working technologies as effects of an *array* of relations that are simultaneously social and material (Law 2000a). On the one hand, technological artefacts themselves are presented as "heterogeneous actor-networks within which both humans and nonhumans are enrolled" (Postma 2009: 165). To function, artefacts must 'front' a range of heterogeneous relations: for instance, an artefact such as a maritime vessel becomes subject to inquiry in terms of how the materially heterogeneous relations that produce it – "[h]ull, spars, sails, stays, stores, rudder, crew, water, winds" – need to hold together for it to be called "a (properly working) ship" (Law 2002a: 95). While artefacts are purely material entities, technologies are not. On the other hand then, a relational account of technology cautions against equating technologies with artefacts. For example, quite obviously all Portuguese vessels are wooden and steel contraptions; however not all ships are technologies for 'marine imperialism'. The implication is that what makes the Portuguese vessel a *technology* for 'long distance social control' (Law 1986 [2001]), cannot be equated with the artefact of the ship. While the artefact is here clearly an important feature of the technology, it is better understood as the material 'tip of the iceberg' of sociomaterially complex and largely open-ended networks of relations that constitute, in this case, the Portuguese empire.

In ANT it is the type of 'relational work' (Medd and Marvin 2008) that particular entities perform which earns them the designation of technology. This is captured by Latour's (1999b: 210) notion of 'techniques', which designate the role of particular entities as mediators of relations (Latour 1999b; 1999a; Postma 2009). Abstractly, techniques are 'things' that *gather* in the sense of bringing entities "from very different seasons, places, and material" (Latour 1999b: 209) together into heterogeneous associations (Heidegger 1977; Latour 1999b; Postma 2009). Techniques can fulfil different mediating roles. They may, for instance, be constitutive of relationships as an ‘intermediary’ (Latour 1990) that travel between actors (such as scientific texts and money); they may foreclose or open up particular modes of activity (such as the decision of wearing a seatbelt while driving, or not (Latour 1994)); or ‘fold’ heterogeneous entities into particular configurations (Murdoch 1998). Crucially, however, while all technologies are techniques (at least whilst they function), not all techniques are technologies. The distinction between technology and techniques is that the former derive their status as such through constituting a particular kind of technique. Specifically, they acquire their ‘technological’ attribute through being inscribed with intentionality in the context of human activity (Akrich 1992). Thus, for instance, while a stone-headed hammer is a technology of handicraft, a stone on its own is generally not considered a technology, unless otherwise enrolled into a human scheme.

While on the surface this is an understanding of technology that is shared between material semiotic and constructivist approaches, there is an important difference between the two. In the latter, new technologies are often understood as lacking stabilisation, and are therefore not being used more widely. Material semiotics, however, does not equate ‘novelty’ with lacking stability or standardisation as such – this would imply that there is in fact a singular entity that could somehow become ‘stable’. It would suggest that there is at some point in time a moment of ‘creation’ of technologies, following which their emergence is one of gradually consolidating and multiplying deployment. Against such a conception of technology, material semiotics rejects a strict separation between moments of physical creation (‘design’) and subsequent ‘use’ of technologies (Kroes 2010). In constructivist accounts, ‘technology designers’ are the active creators of material artefacts who physically inscribe into the material make up of technologies a set of characteristics and anticipated uses. While Akrich (1992: 212; added emphasis) alerts of the possibility of the “reinventing and reshaping [of] technical objects *in use*”, constructivists such as Kroes (2010) reject that, for instance, the act of ‘using a knife as a screwdriver’ constitutes an act of original creation. However, Orlikowski (2010: 137) questions the analytical distinction between design and use. Rather than the finished products of research an development, diffused along an S-curve of adopters or increasing degrees of structuration along which “technology is a relatively fixed set of capabilities that are seamless, stable and the same everywhere and most of the time”, Orlikowski suggests that, through their various practices, humans of all kinds may potentially fashion the reality of technologies. For instance, the Portuguese vessel (inclusive of its winds, currents, astrolabes, crews and many others) as a technology for imperialism, rather than being an 'interpretation' of a ship originally built elsewhere derives its technological status from the relational work that it performed for Kings and Merchants at that particular time. Consequently, from a relational perspective technologies are not materially immutable and functionally singular but acquire their particular technological status as an effect of their role in mediating *particular* relations.

The material semiotic focus on the relational character of technology as a technique thus constitutes an important departure from prevailing understandings of technology in innovation studies. Rather than assuming that technologies mechanically fulfil 'social functions', material semiotics urges to inquire into the precise work that particular technologies perform, for different people, at different times. In this way, material semiotics draws attention to the potentially numerous, simultaneous processes in which the 'same' technology becomes technological for various actors. Such an understanding of technology as an 'effect' constituted by an array of relations that are not necessarily fully coherent or compatible is a promising analytical move for a comparative technological perspective across cities, as it promises to inquire into how it is that technologies become such. Importantly, a material semiotic account of technology increases analytical sensitivities to the possibility that potentially numerous parallel and competing 'versions' of PV co-exist alongside one another, even within the same city. On the one hand, this cautions against presuming, as in *SNM*/*MLP*, that different actors necessarily have similar, compatible or even temporally converging expectations of a technology. On the other hand, it implies that a technological analysis needs to trace the ways in which technologies may serve to mediate very different outcomes in distinct materially heterogeneous webs of relations. This becomes a particularly meaningful argument in particular in Chapter 4, where the intelligibility of an 'urban photovoltaics' is at stake. Critically for the present purpose, this argument has important implications for understanding the very meaning of 'innovation', as is explored in the following section.

2.5.2 Innovation

The second fundamental departure from prevailing innovation studies frameworks implied by material semiotics is related to how innovation itself is understood in innovation studies and frameworks such as *SNM*/*MLP*. Specifically, while 'sustainable' innovation in *SNM*/*MLP* is thought to involve normative interventions targeting the 'unsustainabilities' of some status quo, the *content* of innovation is generally taken for granted rather than interrogated. In innovation studies in general, the word 'innovation' refers to a noun – an idea, product, technology. There is generally little questioning of the precise purpose of the innovation (as seen in the previous section) with analysis focusing, for instance, on establishing taxonomies of innovations; such as according to their degree of novelty (e.g. 'incremental, radical, systemic" (Freeman and Perez 1988; Abernathy and Clark 1985; Kleinschmidt and Cooper 1991). From a material semiotic perspective however, 'innovation' refers not to a tangible object, but is instead understood as an activity that may make use of technologies (such as photovoltaics or imperial ships), but is fundamentally employing these as *means* to an end. The analysis thus veers away from analysing taxonomies and sets of 'rule systems', to overtly questioning what underlies the successful assembly of entities (artefacts and potentially others) as techniques for realising particular purposes. In other words, attention shifts away from the object (innovation as a 'noun') to the practice within which it features (innovation as a 'verb'). Crucially, a material semiotic account of innovation avoids a focus on the artefact in favour of elucidating the range of means by which actors attempt to turn their aspirations (whatever these may be) into reality. As means to an end, therefore, technologies become meaningful as such owing to their potential for bringing about outcomes that are understood as 'desirable' in the context of particular human activities.

Crucially, as emerged over the course of the research, innovation is not straightforwardly – and necessarily – about similar and compatible aspirations for 'sustainability'. Rather, it is often a process shaped by a range of desires for alternative states of affairs; each which involve "the questioning of reality and of the present" through imagining alternatives in "a virtual present or in a hypothetical future" (Vieira 2010: 23). Innovation, in other words, is better thought of as a utopian form of 'ontological politics' (Mol 2002) in which technologies play a particular part as techniques. An exploration of how the existing literature has depicted the processes of innovation is helpful to further develop this idea: when it comes to conceptualising the content of innovative activities, the *SNM/MLP* literature has focused rather narrowly on different forms of 'learning' about alternative possibilities. Learning in this context can be seen as broadening focus from purely research-based activities (e.g. in laboratories) and other commercially-led activities to include 'societal learning' about technology in its use-context (Schot 1992; Schot and Rip 1997). However, within a general focus on learning, debates in the literature have focused rather narrowly on differences between 'technological niches' (Raven 2005; Schot and Geels 2008), 'grassroots innovations' (Seyfang and Smith 2007) and 'urban experiments' (Bulkeley et al. 2010). For instance, *technological niches* are the traditional focus of *SNM*/*MLP*, with particular attention attributed to learning processes and protection which serve to bridge the "'valley of death' between R&D and market introduction" (Verbong et al. 2008: 557). In contrast, "grassroots innovations" are less about creating financially viable products than alternative "new 'systems of provision'" (Seyfang and Smith 2007: 594). Urban experiments, is concerned with reconfiguring the socio-technical networks of the city through experimental initiatives such as public-private partnerships city-scale energy services companies (ESCos) and urban low-carbon 'zones'. Overall, the general tendency has been to focus upon differentiating types of experimental learning from one another. For instance, a distinction is often made between 'first-order' learning about technical functionality and 'second-order' learning values and lifestyles (see Section 2.2.3). However, contributions from an emerging body of scholarship on 'urban' transitions have already questioned whether learning is apt for capturing the breadth of innovative interventions at play in reality.

To broaden our conception about what it means to innovate it is helpful to bring to the fore an important shared feature of technological niches, grassroots innovations and urban experiments. What emerges is that *SNM/MLP* studies implicitly contain the utopian element of a material semiotic concept of innovation, however that in downplaying conflict in favour of consensus these studies fail to ask about the very direction of innovation and its precise content. Significantly, there is a largely implicit shared commitment to the notion that the importance of niches and experiments derives from their potential to lead to 'transitions' (e.g. Geels and Schot 2007; Berkhout et al. 2010; Smith 2010). Whether technological, social or socio-technical and whether emerging through top-down, bottom-up or more 'horizontal' processes, 'technological niches', 'grassroots innovations' and 'urban experiments' are generally understood as the 'seedbeds' that are defined with respect to their promise of bringing about wider, large scale changes in the future (Smith 2006; Schot and Geels 2007). The expressively utopian element contained across types of niches concepts rarely – if ever – receives any systematic attention: the fact that niches somehow hold the promise of redressing the unsustainabilities of the status quo (however these are defined in each case, see Chapter 6). Like the utopias of modernity – gardens and parks, places of education, places of leisure, scientific laboratories (Hetherington 1997) – technological niches promise greener energy futures, grassroots niches consumption practices that are more environmentally benign and urban experiments seek to engender ‘low carbon’ cities (Bulkeley et al. 2010; Hodson and Marvin 2010). Drawing out this utopian element of innovation provides greater scope to account for the politics of innovation, which are often seen as lacking in *SNM*/*MLP*. It creates scope to consider competing aspirations for ‘sustainable’ futures, however defined in practice, alongside one another. This resonates with contributions at the intersection of SNM/MLP and urban studies, such as Hodson and Marvin’s (2012) interrogation of the different sustainability-orientated solutions invoked for Manchester in the UK, which differ depending on who claims to ‘speak’ on behalf of ‘the city’.

To innovate then, is a highly normative enterprise that is intimately tied up with particular ideas about progress and ‘the good’. Significantly, innovation no longer refers to an object, a product or a technology but a process involving attempts by a diversity of actors to convert their visions about desirable states of affairs into the “here and now of the actual production of social space” (Hetherington, 1997: 56). Material semiotics further suggests an interpretation of SNM/MLP in which technologies in niches and experiments as the key means through which future aspirations are made material. The consequence is that innovation is explicitly understood as a ‘spatial’ practice. What, however, precisely counts as innovative practice changes from prevailing understandings. In *SNM*/*MLP* it is rarely questioned that innovation necessarily takes places in niches, on the one hand, and that niches invariably constitute sites of ‘experimentation’, on the other hand. The tendency within the literature is to debate the merits of different ‘niche-internal’ processes[16], including how these lead to constituency building within the niche. Alternatively, contributions have focused on distinguishing ‘first’ from ‘second’ order learning (e.g. Smith 2007), identifying ‘stepping stone’ projects, adding another (‘cosmopolitan’) level to the *MLP*’s three-tier model, or debating the merits of niche ‘protection’ versus ‘exposure’ to the selection pressures (Hommels et al. 2007b; Hommels et al. 2007a). While the field is vibrant and contributions continue to develop and ‘fine-tune’ the framework, up to date it has been suggested, at most, that a broader variety of actors may engage in niche experimentation then previously anticipated by the framework (Späth and Rohracher 2010; Bulkeley and Betsill 2005; Bulkeley et al. 2010; Seyfang and Smith, 2007). It is remarkable that the activities that are ‘non-experimental’ but which may nonetheless have material consequences are relatively absent from current debates. In the

[16] Network building, adjusting expectations and different forms of learning. Niches are defined experimental arenas, perhaps owing to the SNM/MLP’s temporal understanding of ‘interpretative flexibility’ which effectively focuses analysis on those processes which are thought to foster the convergence of expectations.

remainder of this section it is argued that to better account for the variety of ways in which visions and processes of spatialising these relate to one another, it is necessary to move away from a vocabulary of niches and experimentation towards one which is more attuned to, however not prescriptive of, how the utopian aspirations of innovators are translated into spatial practice.

To better conceptualise innovation as spatial practice the framework borrows the notion of 'utopics' from Hetherington (1997) and Marin (1984). For these authors, utopics denotes a type of spatial practice by which 'utopian' aspirations are translated into material outcomes. It captures practices that seek to 'make a difference' but does not prescribe the precise content of changes that different actors may aspire to bring about. Material semiotic thinker Law (2004) calls such interventionist practices 'modes of mattering' (Law 2004b) – ways of interfering with and differently enacting realities. Utopics, can thus be understood as a particular mode of mattering which is concerned with questioning and reconfiguring states of affairs based on future aspirations. Through understanding innovation as a practice of spatialising aspirations and visions into material outcomes, utopics brings into focus the *relationship* between (a potential diversity of) 'visions' of the future, and crucially, the role of technologies in the process of converting these into reality. Crucially, a material semiotic notion of utopics (as opposed to Hetherington's and Marin's original use of the term) provides a more than descriptive account of innovation through incorporating the role that techniques, as discussed in Section 2.5.1, have in utopian spatial practice. Understanding particular entities, such as technologies (and the heterogeneous materials that constitute them) as things that 'gather' positions these as crucial instruments for actors to make concrete, or 'script' (Akrich 1992: 208) their aspirations. For instance, Latour (1992) can be taken to illustrate attempts of translating human intention into practice using techniques: one person's efforts to secure the integrity of a particular door as a barrier against the elements is frequently subverted (a note is not heeded and the human porter falls ill). Paper and human are eventually substituted by a metallic spring mechanism, which ensures the door closes after each visitor. In subtle yet fundamental ways such as these, techniques may mediate the possibility for change.

Rather than narrowly focusing analysis on experimental activities of actors in niches (as so far as these can be identified in the first place – and Section 2.2.4 argued that this is problematic) the notion of utopics draws attention to *any* sort of practice that involves spatialising aspirations through the use of techniques. In particular, it makes it possible, as in Chapter 4, to distinguish different 'modes' according to which actors innovate, depending on how they combine and conjoin different techniques; rather than exploring innovation through a pre-given focus on experimentation and learning, as in *SNM/MLP*. For instance, while technology manufacturers may convert their commercial aspirations about PV into research and development activities, other actors' utopics may involve purchasing the technology to reduce the environmental impacts of their consumption (Keirstead, 2006). While the former act through channelling funds into learning and product development, the latter make a difference through investing financially and metaphorically. Both product development and technology adoption are two types of activity that undoubtedly have material impacts for processes of innovation. A concept of utopics would recognise both interventions as different modes of mattering as the actors' respective means (e.g. finance, knowledge, corporate might and domestic space) are leveraged towards bringing about their (different) aspirations. Thus, a material semiotic account of utopics indicates a focus on practices of spatialising aspirations in general, however rejects setting the precise parameters of innovative practice.

In sum, while able to accommodate the current register of what counts as innovative practice in the *SNM/MLP* framework, the notion of utopics is more expansive than the rather narrow experimental focus on learning in niche activities. Importantly thus, acknowledging that innovative practice may take potentially numerous and multiple co-existing forms is valuable for introducing a more complex account of innovation to that which prevails. Accordingly, it should not be assumed that different actors necessarily apply technologies (as techniques) for 'greening' systems of provision (as in *SNM/MLP*), nor is innovative practice necessarily of experimental character. This focuses attention on the means by which particular technological realities are made – and crucially, by whom and for what purposes. Utopics thus allows for parallel (and potentially competing) notions of the future aspired-to 'good' to exist simultaneously and, importantly, introduces a spatial and normative sensitivity that is frequently thought as lacking in the *SNM/MLP* framework (see 2.2.4). Significantly, it suggests that innovative practice may take not only a variety of directions, but also a range of substantive forms, beyond experimentation. Importantly, however, understanding innovation as utopics signals that innovative practices constitute *attempts* to spatialise aspirations. The concept itself says little about how utopics play out in practice. The challenges that utopics may face in terms of gathering aspired-to outcomes, whatever these are in practice, are explored in the following section. The section will conduct a re-appropriation of the *SNM*/*MLP* concept of 'socio-technical regimes' from a material semiotic perspective.

2.5.3 Regimes

While the *SNM*/*MLP* framework was rejected for framing the research as a whole, this section reclaims the notion of 'regime' from a material semiotic perspective as it enables a valuable portrayal of innovation as an interplay between that which is 'novel' (technology, in its expansive material semiotic sense) and that which is 'normal' (regimes, as developed in this section). Having outlined an understanding of innovation which avoids assuming the shape and content of innovative practice, this section proposes, analogously, that it should not be taken for granted what effects regimes have upon utopics. Very basically, the prevailing understanding of 'socio-technical regime' in the *SNM*/*MLP* framework puts forward a notion of regimes as the dominant 'grammar', the context in which innovation in niches is thought to take shape (Smith et al. 2005; Rip and Kemp 1998). This resonates with prior arguments in innovation studies about the ambiguous nature of standards and standardisation in potentially hindering innovative efforts. Here it is argued here that there is merit in the ambition of theorising 'barriers to innovation', however that the existing *SNM/MLP* concept of 'socio-technical regime' is flawed for being essentialist and descriptive and thus fails to account for the diverse ways in which regimes may be encountered in practice and the variegated character of the relations that produce regime effects. In contrast, while similarly attributing importance to the potentially disadvantageous effects of pre-existing relations, a material semiotic regime concept provides the analytical means to assess the detailed character of regimes and how precisely they impact upon actors' utopics. In order to develop a material semiotic account of regimes this section thoroughly interrogates the *SNM*/*MLP*'s concept. This involves a careful examination of how to conceptualise regimes in terms of identifying the precise relations that constitute them and how these come to bear upon innovative utopics.

While niches and socio-technical regimes share a common make up – of actors, artefacts and institutional rule sets (Geels 2004) – the latter are thought to 'meta-coordinate' activities across different social groups – as a result, constraining niche actors' network building activities. Beyond the standardisation of products in earlier strands of innovation theory, it is the formal and informal institutional processes and procedures that are thought to be streamlined according to particular pre-existing logics. At this point, several commentators (Markard and Truffer 2008; Smith and Stirling 2008) point to a tension between 'institutional' and more 'material' conceptions of socio-technical regimes. While the latter is sensitive to the "structuring qualities" of materials such as artefacts and infrastructures (Smith and Stirling 2008: 7) the former's focus on *human*-centred 'rule-systems' is less attuned to the importance of non-humans in providing stability to otherwise 'social' relations. This institutional (Geels 2004) conception is highly problematic from a material semiotic perspective. ANT scholar's argument is that "the social isn't purely social; and that if it were then it wouldn't hang together for very long" (Law and Mol 1995: 276). For instance, the social space of the 'prison' successfully contains inmates within its boundaries as a result of the combination of both (human) prison guards and (non-human) prison walls. The first departure of a material semiotic account of (the institutional notion of) socio-technical regimes is, therefore, that regimes are materially heterogeneous, rather than made up of cognitive (and largely immaterial) 'rules'. Material semiotics understands the constraining effects as the stability and durability that is effected by associations *between* (human) 'social' and (non-human) 'material' arrangements.

Sensitivity to material heterogeneity of regimes is much better accommodated by the more materialist conception of regimes that Smith and Stirling (2008) defend, however, in both conceptions regimes are understood as fundamentally constraining of innovative efforts as their structural qualities makes it difficult to put in place new 'rules' (Smith and Stirling 2008; Geels 2008). Yet, as Genus and Coles (2008) point out, the rule-based understanding, even in more materially sensitive version accounts of regimes (e.g. Smith and Stirling 2010), while present in theory, is seldom systematically mobilized in empirical *SNM*/*MLP* case studies. In practice, *SNM*/*MLP* scholars tend to allocate either actors (Verbong et al. 2008) or entire infrastructures (Verbong and Geels 2007) to the regime. Here material semiotics signals a second point of departure from the prevailing notion of socio-technical regimes. Specifically, material semiotics rejects understanding 'stability' and 'coordination' as essential properties of particular actors or places. Abstractly, regimes are pre-existing configurations that are in the way of realising ones utopian spatial practice. Crucially, while *SNM*/*MLP* takes regimes as entities that are independently intelligible from the practice of innovating, from a material semiotic position the boundary between that which is 'novel' and that which is 'normal' emerges in practice, "where the *effects* of differences appear” (Barad 2007: 72; added emphasis). An example that illustrates what is meant by this is Murdoch’s (1998: 363) analysis of one person’s unusual dietary requirements: “[a]s someone who is allergic to onions [Susan Leigh] Star, discovers that asking for a burger without onions disrupts the flow along the network in a MacDonalds restaurant and results in a long delay before the food can be served”. In this case, Star’s allergy becomes meaningful and has material consequences in the context of an existing way of preparing (fast) food (it causes inconveniences for both Star and MacDonalds). Star’s voicing of her dietary requirement can be understood as what Barad (2007) terms a ‘boundary-making practice’ in the sense that a distinction is performed between the novelty of Star’s allergy and the inflexibility of MacDonald’s food preparation process. Importantly, the ‘prescription’ (Murdoch 1998) that Star experiences as she attempts to make appear an onion free burger from the kitchen becomes intelligible only through the very *act* of ‘asking for a burger without onions’.

Transposed, the material semiotic argument is that, rather than presuming the existence of differently ‘structured’ niches and regimes, particular forms of novelty and normalcy acquire their intelligibility as such in an emergent manner, as effects of practices which enact boundaries between the ‘novel’ and the ‘normal’. In the case of renewable energy technologies, for instance, techno-economic experimentation may perform regime constraint as related to existing market infrastructures and consumption practices (e.g Verheul and Vergragt 1995; Hoogma et al. 2002). In contrast, approaches that focus on urban ‘low carbon’ experimentations may instead locate obduracy in the materiality of the built environment (e.g. Hommels 2005; Bulkeley et al. forthcoming; Bulkeley et al. 2010). Rather than it being the case that novelty somehow ‘struggles’ against a pre-defined regime of aligned actors and artefacts, material semiotics cautions against presuming that the precise character of novelty and constraint will manifest itself in identical ways in different places; or that there is a single form of constraint that a new technology, such as photovoltaics, may face. Their precise properties and boundaries become intelligible in particular – boundary-making – events that produce the effect of difference. Precisely which ones of the myriad of relations that predate attempts to innovate will cause challenges to innovation needs to be interrogated.

The types of constraint regimes constitute and the relations that make them up become intelligible in boundary-making events which, it is argued, are the practices of innovation –

utopics. A focus on practice and multiplicity uncovers and challenges the *SNM*/*MLP* implicit essentialist understanding of regimes, which tend to render the term rather descriptive. For instance, it is generally assumed that novelty is ‘locked out’ from the standardised circuits of the regime, however, besides the fact *that* socio-technical regimes somehow constrain, little is said about how exactly they impact upon attempts to innovate. For instance, it is fundamentally taken for granted that regimes are necessarily characterised by aligned *networks* of different groups of actors and that they will always serve to ‘lock out’ novelty in the same way. In contrast, a material semiotics approach suggest that regimes, while made up of relations that pre-exist efforts to innovate, may be experienced and enacted rather differently across different actors’ utopics. The merit of understanding regime properties as emergent is that such an interpretation is attuned to the different forms of relationality that may constitute regimes. Material semiotics in the ‘post-ANT’ tradition cautions against naturalising forms of spatiality (see Section 2.4.2) as in *SNM*/*MLP* where regimes are conceptualised as networks that are somehow nested into a territorial spatiality (often, but not exclusively, at the national level). Rather than assuming a particular form of relationality (networked ‘alignments’) and its effect (‘lock out’) understanding the constraints faced by those seeking to innovate must explore regimes *in action*; paying attention to how “actors engage in a constant deployment of their own scales” (Jensen 2007: 833). Constraining relations, in other words, become knowable in practice. A material semiotic analysis implies focusing on how actors themselves “sort the important from the insignificant, and… determine how to act, towards which goals, and in collaboration with which actors” (ibid.; Callon 1986b).

It is rather difficult to make this argument, about different forms of relationality, in the abstract. Rather, applying this material semiotic interpretation of regimes to understanding their heterogeneity of relations and effects will be Chapter 5’s central concern. For now it should be noted that material semiotic sensibilities stimulate a much deeper interrogation into the character of novelty and normalcy as situated phenomena that are constituted spatially to one another. This resonates with contributions from urban technology scholarship concerning the need for analytical sensitivity to the precise social, material, institutional etc. features that produce particular place-based efforts to transform (e.g. Hård and Misa 2008). It also promises to speak to the emerging relational urbanism literature through enabling to connect and contrast regimes’ spatial reach and quality. Chapter 5 will illustrate that the merits of applying a material semiotic understanding of regime are considerable, relating to the possibility of distinguishing several ways in which regimes impact upon efforts to innovate and how a range of spatial metaphors might be deployed to capture a diversity of relational regime constellations. Not only does such an understanding promise to avoid the descriptive and essentialist tendencies of *SNM*/*MLP*'s 'socio-technical regimes'; as the next section now turns to, it also brings to the fore questions concerning the conditions and prospects for transforming that which is already in place.

2.5.4 Transformation

The challenges of introducing novelty into existing arrangements, such as constituted by regimes, is that regimes often preclude the formation of alternative possibilities. Attempts to innovate, in other words, face the challenge that novelty is frequently marginalised in existing practices. For instance, Star's onion allergy is marginalised in existing fast food processing and largely disarticulated. However, Murdoch (1998: 364) notes that the way Star is able to remove the onions from the burger (after conforming to ordering 'with') indicates that even strongly coordinated set ups are not "complete, closed totalities". While novelty – whether an allergy, a technology or other – faces the difficulty that it is conditioned by regimes, it is also the very existence of a 'status quo' that is a precondition for 'change' to take place. For instance, Star would not have been able to order 'onion free' in the first place without the prior existence of the fast food restaurant. Casting the distinction between novelty and normalcy as emergent (rather than essential) enables a portrayal of boundary-making practices (through which differences between novelty and normalcy are enacted) as making intelligible the prevailing 'conditions of possibility' (Foucault 1986; Barad 2007). These are "that which constrains and enables what can be said" (Barad 2007: 146); and crucially, they are 'material-discursive' in the sense that they "enact what matters and what is excluded from mattering" (ibid. 148). Understanding the outcomes of innovation as potentially altering the conditions of possibility enables the development of a relational understanding of change, which is a fundamentally different approach to framing transformation than is presently proposed by the *SNM*/*MLP* model.

The latter considers that localised experiments in niches may reconfigure or even entirely displace incumbent regimes when niche networks of actors 'grow' by becoming more 'stable' and coordinated; a process which is often thought to occur in the context of landscape 'pressures' and regime 'incoherences' (Geels et al. 2008). However, even commentators from within the broader field note the model's risks of oversimplifying complex and variegated processes and outcomes

(Smith et al. 2010; Shove and Walker 2008; Coenen and Truffer 2012). Most notably, Smith (2007: 447) cautions against a simplistic account by which niche novelty simply replaces incumbent regimes. By distinguishing three forms of ‘niche-regime translations’ he proposes that the “literature on green niches must pay greater attention to niche–regime interaction”. However, while agreeing with Smith’s critique, a material semiotic position is more far-reaching in terms of fundamentally questioning the basis from which (niche) ‘novelty’ can be distinguished from (regime) ‘normalcy’; rejecting to tie the respective normal and novel properties to particular actors and places (as, for instance, Verbong et al. (2008) do). From a perspective that is sensitive to the dynamic interdefinition of the novel and the normal, material semiotics understands ‘transformation’ as the reconfiguring of the conditions of possibility – i.e. how that which pre-exists is – somehow – made permeable to alternative material and discursive possibilities.

Such an understanding of change implies reconceptualising how *SNM*/*MLP* understands the nature of transformation. In *SNM*/*MLP* several ‘ideal types’ of niche-regime interactions provide general ‘trajectories’ of transformation, such as ‘transition’, ‘reconfiguration’ and ‘reproduction’ (2007). However, for Smith et al. (2010: 435 and 445; added emphasis) it is not enough to merely ‘locate’ the emergence of novel behaviours in niches, as this fails to explain “*how* and *why* such “greener” production and consumption practices come about …*how* and *why* individual agents are able to reform the rules in desirable directions”. While the ‘niche-internal’ mechanisms of ‘learning’, ‘network building’ and ‘expectations’ are – arguably –useful ways of describing the outcomes of niche activities, it is surprising how little attention has been attributed to the interactional work that goes into the emergence of ‘rules’ (whether these are ‘cognitive’, ‘regulatory’ or ‘normative’, as in Geels (2004)). In other words, how is it that greater degrees of structuration or standardisation emerge, and how do pre-existing streamlined relationships bear upon these processes? The lack of accounts of rule-emergence, it is argued here, is related to *SNM*/*MLP* theory’s fundamental failure to implicate the presence of nonhuman materials and spaces into processes of innovation. The argument is largely analogous to the previous sections’ about the material heterogeneity of regimes. Lovell (2005: 2500), for instance, notes how housing materials and other technologies are the “substance of policy” that critically enable (though do not determine) the emergence of different eco-housing policy storylines and the formation of alternative discourse coalitions. Thus, rather than “sidelining the physical characteristics and capabilities entailed in particular technological objects” (Orlikowski 2010: 133), a materially sensitive account of transformation draws attention to the importance of technologies in mediating transformative outcomes.

Rather than needing to 'upscale' and 'displace' technologies may impact even without becoming standardised configurations. Here the notion of technology as 'technique' becomes critical for conceptualising the role that technologies such as PV may have in transforming the conditions of possibility.It was previously noted that technologies act as techniques for purposefully gathering particular relations (Section 2.5.1). Subsequently, Section 2.5.3 noted that innovation can be understood as processes of spatialising utopian aspirations. At present the notion of technology as technique and innovation as utopics can be combined into the notion of 'utopical technique' to indicate that actors may apply technologies to transform the conditions of possibility according to their particular aspirations for change. Importantly, understanding technologies as things that 'gather' suggests that technologies are crucial in terms of making it possible for actors to make concrete, or 'script' (Akrich 1992: 208) their way of spatialising aspirations – to "define a framework of action together with the actors and the space in which they are supposed to act" (see Section 5.4.1). This aspect of technologies is thoroughly sidelined in frameworks such as the *SNM*/*MLP*, which tend to equate the proliferation of a technology with the accomplishment of utopian aspirations; with important implications for how the dynamics of transformation are conceptualised.

It is assumed that renewable energy technologies, for example, will produce more sustainable outcomes simply by virtue of being 'green'. In cases where niches are understood as successful the theory casts this as a gradual (temporal) move from exploratory experiments to pilots, demonstration and dissemination (Geels and Raven 2006); and (spatially) from localised, small-scale experiments to the 'inter-local', 'trans-local', 'cosmopolitan' and eventually regime level (e.g. Bulkeley et al. 2010). Critical contributions (Rohracher 2008; Smith and Stirling 2010; Smith et al. 2010) have questioned how traditional notions of space – such as the urban, region and even more 'local' community level – 'fit' into this model. However, rather than debating about how to "unpick 'nests' of niche, sectoral and system-wide 'levels'" (Genus and Coles 2008: 1442), a relational understanding of regimes suggests that these debates are fundamentally misplaced: whatever the 'right' spatiality, the rather smooth and 'macro' portrayal in the *SNM*/*MLP* framework is fundamentally at odds with a materially sensitive account of technologies as utopical techniques. Instead of adding more spatial imaginaries, the task of evidencing change becomes about assessing the gathering effects that technologies such as PV may have in terms of bringing about qualitative shifts in the relations that are already in place, whatever territorial or other spatiality they perform.

Crucially, it is not assumed that technology necessarily produces the utopian outcomes desired, as it is not a given that a utopics will be successful. Utopia, in the original sense of the term coined by sixteenth century writer Thomas More, collapses the Greek for the 'good place' (eu-topia) and the 'no-place' (ou-topia) into one another – utopia, 'perfect sites with no real place'. The notion that aspirations refer to no-places of the imagination constitutes a fundamentally different account from the *SNM*/*MLP*'s temporally linear expectation convergence and spatially expansive process of 'up-scaling'. In fact, Law (2000a: 10) notes the frequent occurrence of failure to transform: "[w]recked ships. Failing vaccines… a huge literature in STS about the demise of technical objects". If what makes particular technologies 'technological' is the way in which they are intended to change the conditions of possibility, then analysis ought to trace the extent to which a technology is a 'utopical success'. This can be done by using ANT-inspired sociologist Hetherington's (1997) re-interpretation of the Foucaultian notion of 'heterotopia'. Literally, 'heterotopia' is Latin for 'place of otherness'[17] (Hetherington 1997; St John 1999). Hetherington's particular take on heterotopia seeks to capture the drift that exists between utopian *ideals* (about, for example society and how it should be organized) and the *actual* spaces and places that are realised as a result of translating these ideals into practice. Hetherington argues that actual spaces can never truly be utopias because attempts to spatialise aspirations (i.e. utopics) are generative of ambiguities, uncertainties and unintended consequences. Instead of producing the 'perfect' places envisioned by the mind, the outcomes are heterotopia: "where efforts… to turn the nowhere of the imagination into the good place… are invariably 'in-between' such ideals" (St John 1999: web-based).

Importantly, heterotopia are very different from niches, as they do not suggest that sites of novelty are located at the bottom of a hierarchy of ascending 'structuration' (see Figure 2.1). instead, heterotopia are relational sites. As opposed to niches, which are sheltered, 'local' and set

[17] In its original use in the study of anatomy heterotopia refers to "parts of the body that are either out of place, missing, extra, or, like tumours, alien" (Hetherington 1997:42).

apart from the ‘meso’ and more de-territorialised regimes, heterotopia are ‘in between’ spaces of alternatives which provide “a new perspective on the old order and its faults” (Hetherington 1997: 50). Their significance derives from the way they unsettle the prevailing conditions of possibility by constituting “another way of acting or ordering against that which prevails and dominates” (ibid. 50). While treated non-concisely by Foucault (2003; 1986) himself heterotopia has been used to denote a variety of ‘marginal’, ‘liminal’ and ‘paradoxical’ spaces, which are sites of “socially transgressive practices”, ambivalence and a “multiplicity of social meanings”, that are “marginalised within dominant social spatialization” (Hetherington 1997: 41; Shields 1991;Genocchio 1995). While heterotopia are thus understood as (sometimes celebrated, sometimes reviled (Foucault 1986)) sites of otherness, they are not, like niches, orchestrated and ordered. They come into being precisely because of the deferral that exists between the utopian ideal and its conversion into practice. The outcomes of attempts to orchestrate necessarily deviate, or ‘drift’ into imperfect and partial versions of the original utopian intention. This is because utopics necessarily runs into other relations, whether these are regimes or others’ utopics.

For evidencing change, this draws attention to the need to interrogate actors’ utopics, as these are the very practices that perform the conditions of possibility and heterotopic transformations. Importantly, this is likely to implicate a multiplicity of heterogeneous actors who are each seeking, through different techniques, to convert their diverse aspirations into actual states of affairs. The question of transformation is thus one of degree: the extent to which techniques successfully convert aspirations, which in each case may be defined according to a different measure. Heterotopia can thus be understood as constituted through the engagement of multiple and heterogeneous ordering strategies (Hetherington 1997). As these operate relationally, somewhere between the taken for granted conditions of possibility and actors’ various utopian ideal this will require a different approach than simply adding spatial or ‘structurational’ categories to the *SNM*/*MLP*’s framework. Rather, the relational character of heterotopia suggests that transformation may involve a diversity of multiple and intersecting spatial forms. And rather than taking these for granted as is the tendency in the *SNM*/*MLP* framework, they should be traced as emergent, as transformation is both “space-forming and space-contingent” (Soja 1980: 211). Thus, while numerous intersecting utopical techniques may transform, they will do so heterotopically as they are fundamentally shaped – enabled and limited – by the conditions of possibility of that which is already in place.

2.6 Conclusion

This chapter developed a conceptual framework based on lines of inquiry as present in contemporary approaches in innovation studies, a thematic engagement with perspectives on urban technology and ANT and post-ANT material semiotic analytical sensibilities (see Table 2-1). Innovation studies sets up an overarching concern with the potential of *innovation* in *technology* to lead to the *transformation* of existing *regimes* towards greater sustainability. Insights from urban technology scholarship are used to raise awareness of the need for a more careful engagement with the inherently ambivalent nature of technology, the numerous sites in, and means by, which change processes are contested and the geographical contingency of the possibilities for far-reaching change to take place. However, while innovation studies provides the general directions of inquiry and perspectives on urban technology crucial thematic orientations, the conceptual framework is rooted in material semiotics. This is because innovation studies frameworks are conceptually limited in several important ways (Section 2.2.4) and urban technology scholarship is rather fragmented in terms of intellectual origins, conceptual approaches and empirical foci (Section 2.3). The chapter moved gradually from a critical review of the existing innovations literature, an exploration of perspectives on urban technology to introducing ANT and post-ANT material semiotics to outlining the original framework that derived from engaging with questions of innovation from a material semiotic disposition. Through engaging questions of innovation with ANT and post-ANT it was possible to establish a shared concern between innovation studies and material semiotics regarding the emergence and establishment of novelty. This made possible the development of a framework that is sufficiently encompassing for the empirical complexity and conceptually attuned to the research questions of this thesis.

The concepts developed in Section2.5 will serve as this thesis' conceptual framework. In the first instance, '*utopical techniques*' is a term used to theorise the nature of technologies such as PV. It cautions against equating technologies with their artefacts, as functioning technologies are understood to be the effects of a variety of heterogeneous materials. From a material semiotic perspective working 'technologies' are sociomaterial entities endowed with purpose in the context of human activity. They are technological based on their application to bringing about desirable outcomes – whatever these may be in practice. The act of spatialising aspirations using technology is theorised using the term '*utopics*' – spatial practice with intent, guided by aspiration. It is more expansive than the existing *SNM*/*MLP* imaginary of experimentation and learning, providing scope for a broad diversity of ways in which actors seek to translate their aspirations into actual states of affairs. The challenges facing utopics are captured by the notion of '*regimes*', a term reclaimed from its use in the *SNM*/*MLP* framework. While it continues to refer to those relations that predate efforts to innovate, a material semiotic understanding of regime remains open about the precise shape of regime relations and how their effects are experienced by those innovating. Rather than a preconceived notion of regimes, it is argued that they should be investigated 'in action' through an engagement with actors' practices in order to capture the geographical contingency of regimes in practice. The transformative outcomes of innovation occur as utopics and regimes diffract, engendering '*heterotopia*'. These are sites characterised by a transformation of the conditions of possibility that are somewhere in between the 'normal', the 'novel' and the aspired-to 'good'. Here the framework rejects the *SNM*/*MLP* smooth imaginary of converging and upscaling niches which interact with, reconfigure or replace socio-technical regimes in favour of an account that seeks to capture the contested, impartial and spatially variegated character of innovation.

Put together, utopical techniques, utopics, regimes and heterotopia form the conceptual lens through findings concerning innovation in urban photovoltaics are presented in Chapters 4-6. The significance of shifting from prevailing innovation studies frameworks is that material semiotics does not take for granted what precisely technologies do, what shape they (or their 'contexts') take and what impacts ('sustainable' or other) they have. Instead, these are taken to be the very questions of innovation. The material semiotic framework thus indicates a shift away from essentialist notions in favour of an approach that is concerned with questions of materiality, relationality, performativity and multiplicity. This provides scope to do justice to the issues of politics and geography raised by perspectives on urban technology, whilst eschewing the limitations of existing accounts in innovation studies. It is the epistemological openness to what the research may reveal that distinguishes this thesis' material semiotic methodology from current approaches in the field of innovation studies. Importantly, the implications of a material semiotic position exceed the purely conceptual. Material semiotics is as much a theoretical position as it is a methodological disposition. The methodological implications for researching innovation in urban photovoltaics are explored in the following chapter, Chapter 3.

Table 2-2 Summary of the framework for innovation in urban photovoltaics

	Technology	Innovation	Regimes	Transformation
Innovation studies (*SNM/MLP*)	An artefact endowed with intrinsic ('green') attributes	Experimentation, learning, network building	Aligned networks of actors that 'lock out' novelty	Transitions through 'upscaling' and 'convergence'
Urban technology critique	Ambivalent nature of technology	Multiple sites and means of transformation	Geographical contingency	Contested and spatially complex
Material semiotic concepts	**Utopical techniques**	**Utopics**	**Regimes**	**Heterotopia**
Significance of MS concepts	Relational means for gathering aspired-to outcomes	Attempts to spatialise aspirations using utopical techniques	Heterogeneous relations that enable and constrain utopics	Outcomes in-between utopics and regimes
Characteristics of MS concepts	Sociomaterial entities endowed with purpose	Causal imaginary linking intervention to outcomes	Intelligible from utopics	Spaces of alternative from status quo

3 Translating material semiotics into research practice

3.1 Introduction

This chapter outlines the implications of a conceptual material semiotic position upon the research design, data collection and analysis of this thesis. As explored in the previous chapter, material semiotics provides the researcher with 'tools' and 'sensibilities' (Barad 2007), and as with its implications for theory, it is not prescriptive of any particular and specific research methods. As this chapter outlines, it does, however, imply researching innovation in a rather different manner from existing approaches. The previous chapter introduced material semiotics as concerned with issues of relationality, materiality, multiplicity and performativity. Beyond abstract theorising, this chapter is concerned with developing a material semiotic research strategy that details a research methodology and specific methods, namely that of 'tracing associations'. This is done by applying material semiotic sensitivities to questions of innovation in a manner sensitive to themes of urban technology scholarship. Importantly, central to material semiotics is the inseparability of questions of ethics, epistemology and ontology in research practice (that is, of valuing, knowing and being). This acknowledgement, of the active role of the researcher in shaping the very phenomena investigated, requires an increased awareness of, and accountability to, how one conducts research – including design, data collection, and analysis. Reflections and justifications of the approach taken thus pervade this entire chapter.

As such, the first section should be seen as an entry point into, rather than full treatment of, questions of positionality. Having set up the general framing of the research based on an 'ethico-onto-epistemological' (Barad 2007) position, the chapter develops the general approach taken as a 'case study' approach, which is understood, following Castree (2005), as 'processual' rather than 'categorical'; that is concerned with exploring 'innovation in urban technology' as a process case study rather than comparing unique instances of a phenomenon ('urban photovoltaics') in three distinct 'contexts' (European cities). This is done by mobilising an understanding of 'comparison' as present in an emerging 'relational' urban comparative scholarship, with two related implications: on a basic level, to treat comparison as itself implicit to the very process of knowledge creation and on a practical level, rejecting the a priori impermeability and inseparability of different geographical contexts. Guided by material semiotics as a strategy, this translates into a methodology of 'tracing associations'. Comparison becomes a strategy for 'unexpected', otherwise taken for granted connections, similarities and differences to emerge from the research as opposed to predefining that which is compared beforehand. Limitations, which are inherent to any research project, are flagged up as relevant throughout the chapter. The chapter outlines what tracing associations means for the data collection process by describing what precisely counts as 'data' (and thus what was collected), the different stages of data collection and the issues different forms of data collection raised. Moving towards analysis, the chapter outlines several stages ('cycles') of analysis: exploratory coding, the construction of narratives and timelines, a sociomaterial analysis, and the comparative cycles; each time reflecting on the cycles' and methods' significance for a material semiotic approach.

3.2 Ethico-onto-epistemology

> [as researchers] we too are part of the world's differential becoming…we make knowledge not from outside but as part of the world… making knowledge is not simply about making facts but about making worlds … which practices we enact matter – in both senses of the word.
> (Barad 2007: 91)

Claims of 'naked' knowledge void of contextual embedding arouse suspicion, in particular considering that as human persons, researchers bear the "imprint of a larger culture and society, and [that] entering into a research relationship implies personal as well as political associations" (Ley and Mountz 2001: 244). In this context, 'reflexivity' is generally understood as the critical scholarly practice of acknowledging the researcher as a formative constituent of representational practices of knowledge creation, where factors such as gender, race, class, religion are thought to shape scholars' ability to accurately know and represent reality (Rose 1997). While aligning with the basic thrust of 'reflexive' practice – to enhance sensitivity to the researcher's person in scholarly practice – Karen Barad (2007) critiques forms of reflexivity that are based on what she calls 'representational' metaphysical assumptions. Barad, following feminist scholars such as Haraway (1996), takes issue with the notion that a mind-independent reality 'out-there' can be known and ‘represented’ accurately and unproblematically through research practice. Instead of a position of exteriority to the object of study, Barad (2007: 88) situates the knower as involved in understanding “the world from within and as apart of it”; and as such one is necessarily implicated simultaneously in acts of being, knowing and valuing. The implication is that ‘reflexive practice’, of being accountable to ones role in the research process, ought to break down the separation of questions of epistemology, ontology and ethics; resulting in what Barad (2007: 90) terms ‘ethico-onto-epistemology’.

Several contributions from the broad field of science and technology studies (STS) are kindred to Barad’s ethico-onto-epistemology. For instance, Law’s performative material semiotics understands the researcher as fundamentally and inextricably implicated in performing a particular, reality-creating and potentially -altering (thus, ‘ontological’) politics (see also Osborne and Rose ; Callon 1998; Mol 2002). Fundamental to this argument, often summarised as ‘the performativity of method’ (Law 2004a), is the notion that (both natural and social) scientific research practices “do not simply describe the world as it is, but also *enact* it” (Law and Urry 2004: 391; added emphasis). This urges for reflexive sensitivity to the precise methods of investigation employed, as these yield not simply more or less accurate representations or reflections of a singular social reality ‘out-there’. Rather than merely offering different (epistemological) *perspectives*, the researcher is seen as, along with the subjects researched, implicated in (ontologically) enacting a particular version of social and material reality (Lees 1999). A researcher’s practice in Barad’s and Law’s performative, ‘non-representational’ sense requires awareness and accountability to the ways the researcher is enacting both objects and subjects of study. In other words, it is not the case that the particular reality of a phenomenon is portrayed in a particular manner owing to the researcher’s person, but rather that the very person of the researcher is the preconditions for knowledge to be created. As such, the notion that research method is unavoidably performative of particular realities implies that the researcher’s person does not only inflect the sorts of knowledges created (epistemologically), but to recognise that knowledge creation is an ontological and ethical process of *making worlds.*

Having set out the general principle of an ethico-onto-epistemological understanding of research practice, the following subsection provides a reflection of how the multi-stake-holder starting point of this PhD shaped the initial impetus behind the project and its early directions. Specifically, the following paragraphs detail *my* understanding of the origins of the project with respect to how it matters for the different parties involved, and how this influenced how the project took shape.

3.2.1 A multi-stakeholder starting point

From the outset, this PhD project has been marked by the involvement of multiple parties from very different backgrounds, including public and private sector (industry) sponsors, senior academics who drew up the initial research proposal, and of course, myself. With respect to myself, the very initial thrust behind my interest in the topic of this thesis was a curiosity and normatively driven concern about wanting to understand why a technology such as PV, with potentially great environmental benefits and electric potential, has been slow to become implemented. I first encountered photovoltaic technology during my MSc in physical geography at King's College London in 2006-7. The 'dissertation' module required MSc students to apply the methods learnt over the course of the masters to a subject of our choice. I chose, rather arbitrarily, to apply geographical information systems techniques (GIS) and numerical modelling to conduct an 'assessment of the theoretical potential of photovoltaic electricity generation in the pan-tropical terrestrial regions'. Besides a general environmental awareness and basic knowledge of solar technologies this exercise convinced me of the great potential that photovoltaics has in terms of contributing towards meeting human electricity demands from renewable sources. As the masters drew to an end, I came across a PhD studentship at Durham University entitled 'Solar Cities in Europe'. I was immediately drawn to the idea of pursuing my interest in researching how such a 'sophisticated yet elegantly simply' technology (which was my perception of PV at the time) was not being used more widely.

The project was advertised by two academics in the Geography Department at Durham University, Harriet Bulkeley and Karen Bickerstaff (two of my academic supervisors). It was a 3-year studentship which was fully funded by *Sanyo Europe Ltd* (a major Japanese electronics manufacturer) and the *County Durham Development Company* (*CDDC*), Durham County Council's business support arm, through the 'Sanyo Durham Legacy Fund'. The latter was an outcome from a decision made by Sanyo in 2001, to close its microwave oven manufacturing plant in the Northeast of England, which had been operating in Newton Aycliffe since 1988. Following my application to Durham, I was invited to be interviewed by representatives from Durham

Geography, Sanyo and the *CDDC*. Each party came with its own assumptions, ambitions, questions and requirements. For the sake of providing an overview of these I compiled Table 3-1 which collates extracts from a press release[18] which was made public after I was accepted as PhD student on the project. The statements from Stewart Watkins (*CDDC*), Kamil Shah (*Sanyo*), Harriet Bulkeley (Durham Geography) and myself indicate that we each came from different positions to the research: *Sanyo* placed the project under its ‘corporate social responsibility’ part of the website, the *CDDC* saw the legacy fund as potentially benefitting the region, Harriet Bulkeley as an exciting cross-departmental research project, with a focus on her ‘cities and climate change’ research, and myself to understand green innovation and dispel myths about solar PV.

Multi-stakeholder research projects have the potential to raise a variety of challenges (Macmillan and Scott 2003; Bulkeley and Betsill 2003). However, my experience of being funded by organisations from different sectors and led by academic supervisors who had had a substantial input in the project’s initial design did not cause frictions that have been identified in the literature, such as ‘ambiguous ownership’, mismatched expectations, ‘messy compromises’, or a ‘client’ relationship with funders (Macmillan and Scott 2003). It was, however, the case that the nature of the relationship between researcher and funders was not set out clearly from the start, leaving me to explore to what extent *Sanyo* and the *CDDC* would treat the project as a ‘partnership’ between industry, the public sector and the department of Physics (as Professor Bulkeley proposed at the outset (see Table 3-1). Following her lead, I proposed visits to both the *CDDC* (in Durham) and Sanyo’s headquarters (in Durham and Watford, respectively), and sent regular updates. Both sponsors tended to reply to these updates and suggestions after mostly a relatively short period of time, with encouragement and supportive language. Contrary to what might have been expected from an industry-funded studentship with a public sector partner, both stakeholders took a distant and ‘hands-off’ approach, perhaps owing to the nature of how the former positioned the project within their own activities (as corporate social responsibility (http://uk.sanyo.com/About-SANYO/Corporate-social-responsibility/) and the latter given the projects non-local focus (large cities in Europe).

[18] It should be noted that press releases such as the present one are the product of particular times and places. In this case, Sanyo had left County Durham with a legacy fund after closing its microwave oven factory in the region. A monetary grant awarded to the Department of Physics for research into PV technology was split into several funding pots, one of which I was eventually the beneficiary. The quotations represented in Table 3-1 should be read with this background in mind.

Table 3-1 A multi-stakeholder project
(Source: personal communication with Parker, M., November 2007)

Kamil Shah, Sanyo Europe Ltd (External Relations)	Stewart Watkins, *CDDC* (Managing Director)
"The Sanyo Legacy is the result of a financial contribution to the North East region to thank local authorities and the general public for supporting the activities of Sanyo Electric over the years… The Sanyo Studentship was created out of the Legacy to help with funding research at Durham University and to ensure the university builds on its strong links with business."	"The Sanyo legacy offers the opportunity to invest in research that has the potential to make a major difference to the County Durham economy. This study is important in terms of how we as a region exploit solar photovoltaics in the future."
Harriet Bulkeley, Durham University (Professor)	**Anne Maassen, Durham University (incoming graduate)**
"The studentship is an innovative partnership between Sanyo, the university and *CDDC*. The project will bring together the knowledge of the university's geography department… with the knowledge the physics department has on solar photovoltaics. It is the first time the two departments have worked together on a project like this… We are specifically interested in the way some cities in Europe are using solar energy more than others. Some cities in Germany have a lot more photovoltaics than cities in the UK where there are similar environmental conditions – similar sunlight, similar climate."	"The aim is to make people more aware of solar energies and that they are considered realistic sources of energy. It is often seen that solar energy does not really work well, particularly in Northern and Western Europe. We want to uncover the myths and prove that this is not the case… We will also look at the funding structures in place to encourage the use of solar technology. It is all well and good if people are passionate about it but if there is no money to support it, who will use it?"

I visited the *CDDC*'s headquarters in Aykley Heads (The Rivergreen Centre, Durham) twice over the course of four years to lunch with Catherine Johns (Director of Innovation and Development) and Stewart Watkins (Managing Director). During these lunches I updated the *CDDC* on my progress and learnt about *CDDC*'s activities, on a very informal basis. In December 2010 Catherine invited me to speak about my research findings at a cross-sectoral national conference on solar energy ('Solarflair' at Lumley Castle, County Durham), which the *CDDC* organised. With respect to Sanyo, the company was relatively less involved than the *CDDC*. On one occasion my contact at Sanyo, Kamil Shah, invited me to meet a team from Sanyo that had come over from Japan to a large European solar industry exhibition (*EU-PVSEC*) in Valencia (in September 2009). There I had a meeting with Dr. Maruyama (General Manager of Sanyo's Solar Energy Research Department in Kobe City, Japan). We exchanged ideas about PV in urban settings during an informal meeting in a hotel lobby, and I gave him a book on Durham as a gift according to Japanese courtesy, which was purchased through the research budget). Later the same evening I was invited to join the Sanyo team for dinner. This was an informal occasion during which I spoke to every member of the team for a few minutes in English (see Figure 3.1).

Neither external project partners made attempts to change the substantive direction of the project after the studentship had been set up by Harriet Bulkeley and Karen Bickerstaff. With respect to taking up a project that I had not myself been part of designing initially, this meant that the process of taking ownership of the project was more gradual than is perhaps the case with other PhD projects where the student is the principal project designer and proposer. As a result, the substantive content of the project (urban photovoltaics in different European cities) was largely pre-given, as well as a broad interdisciplinary theoretical orientation (a 'socio-technical' perspective that would challenge so-called 'techno-economic' accounts of innovation). This derived largely from Harriet Bulkeley's interest and cities and climate change (Bulkeley 2000; 2003;Bulkeley and Kern 2006), Karen Bickerstaff's interest in 'socio-technical' approaches, and both academics' interest in overseeing the development of an interdisciplinary framework about the relationship between technology and society. Coming from an interdisciplinary background myself, equipped with linguistic fluency in several European languages and a desire to do fieldwork outside of the UK, these features were important drivers for me to apply for the project in the first case. As such I broadly aligned with the original research proposal (for full version, see Appendix E). However, over the course of taking ownership of the project I adapted the research questions from the original proposal. The changes are relatively minor and the core concerns of the original questions carried over into shaping the research process.

Having set out the initial impetus behind the project in terms of the multi-stakeholder nature of the research and the implications this had in terms of shaping the early directions of the project, the chapter now turns to explore the overarching framing of the PhD project as a 'case study' approach.

Figure 3.1 Meeting the Sanyo team at the EU-PVSEC, Valencia 2009
(Source: author's)

3.3 A case study approach

The broad approach that this thesis takes to understanding innovation in urban photovoltaics is a 'case study' approach. This was a natural choice considering that case studies are popular approaches in urban and innovation studies (Castree 2005; Ward 2010; Robinson 2008). In an authoritative treatment of case study as a research strategy Yin (2003) proposes that case studies are well-suited to investigating unfolding phenomena within their "real life" contexts (see also Simons (2009)). According to Hesse-Biber and Dunleavy (2011: 256) a case study approach

> provides the researcher with a holistic understanding of a problem, issue, or phenomenon… because the case is investigated from many different angles and pays attention to many different dimensions of the issue, case study is typically able to avoid the kind of essentialist and context-free analysis… allow[ing] for a highly complex and nuanced understanding of the subject of inquiry.

In the context of this thesis the project was initially understood as a 'multi-case study' of innovation in urban photovoltaics in three different European cities. Traditionally, one of the defining characteristics a case study is its 'boundedness' (Silverman 2000: 127). However, through becoming exposed to emerging literatures on 'relational' comparison in urban studies (Ward 2010;

McFarlane 2010; Robinson 2011; Hart 2004), I began to reflect more deeply on the nature of comparison. This led me to reconsider, at a later stage of the research process, what I considered to be a 'case'. It became evident to me, on the one hand, that what appeared to be a well-defined focus on *urban* photovoltaics in *three* urban European settings was much more difficult to uphold in practice. Urban PV was, in Law's (2003: 5) words "a slippery phenomenon, one that changed its shape, and was fuzzy around the edges". A relational understanding of urban PV (such as implied by a material semiotic conceptual framework) meant that case study boundaries kept receding, as an increasing number of relations became apparent during the research process. As a result, I reconceptualised my initial framing of a three-way case study approach of geographical contexts as a single case study of 'innovation in urban photovoltaics'. This move was related to the gradual consolidation of a material semiotic conceptual framework over the course of the PhD which was influenced by the emerging literatures on relational comparative urbanism. Rather than seeing this as a weakness it is proposed here to follow Latour (1996: 91) in admitting that "projects drift; that's why they're called research projects". The implications of this grounded emergence of the conceptual framework and its shaping of methodological issues is considered in Section 3.6.

Crucially, the reframing that took place did not generate incoherences with respect to the initial selection urban areas that I selected as research sites, nor did it affect the data collection stage. It did, however, significantly influence how I conducted a comparative analysis of the data collected – this is discussed in more detail in Section 3.5.4. At present the chapter turns to outline how three different European urban contexts were chosen as 'most different' case studies of urban photovoltaics.

3.3.1 Selecting 'most different' urban contexts

Becker (1998) states that selecting case studies is closely related to the particular research questions at hand; while Hesse-Biber and Dunleavy (2011: 258) further note that "multiple case studies are studied together to investigate a larger phenomenon" (see also Stake 1995). As the research questions are geared towards establishing the evidence of PV being used and the 'factors' involved in innovation in urban PV, this was interpreted as translating into a multi-case study approach which would compare and contrast through juxtaposing different urban contexts. The selection of Barcelona, London and Paris as three urban contexts for comparing innovations in urban PV was conducted based on the merit of selecting what several scholars have termed 'most different' case studies (Tilly 1984; Brenner 2001). The comparison of 'extreme instances' of a phenomenon is thought to make the researcher "aware of new and unexpected connections" Pickvance (1986:163; cited in Robinson 2011: 12) and avoid letting very specific "locally-derived conclusions circulating as universal knowledge" (Robinson 2011: 10; Pickvance 1986).

A desktop scoping study of different European, national, regional and local/urban PV initiatives conducted at an early stage of the PhD project focused the case selection on *large* European cities. This was thought a worthwhile focus as such contexts are marked by relatively greater institutional complexity, morphological density, and importance in broader processes of climate change mitigation and adaptation (e.g. Betsill and Bulkeley 2008). Within the European context, Barcelona (Spain), London (UK) and Paris (France) were chosen as 'most different' (European) case study contexts (from an initial shortlist that also included Berlin (Germany)). This shortlist acknowledged that, by virtue of their common European context, these cities shared the following important features in common: for instance, as large urban centres, which are economically speaking of significant importance for their regional and national contexts, all three cities find themselves in situations of growth, both in terms of prospected populations as well growing energy demands; they are experiencing similar parallel trends putting pressure on traditional infrastructural logics across geo-political boundaries (the liberalization and privatization of energy markets, the tightening of environmental standards, economic costs of environmental modernization, and the proliferation of new technologies (Graham and Guy 1995; Guy et al. 1996; Moss et al. 2001)). Importantly, the three cities' urban authorities recognise climate change as a policy imperative and position themselves as 'leading by example' in climate protection, having conducted urban carbon audits and devised climate change and energy strategies to tackling emissions in the city. However, beyond superficial similarities, the substantive difference between the cities qualified them as 'most different' within this largely shared European context: specifically, relating to climate, national technology policy, and urban development trajectories.

As the intention was to include a UK case study, London was a natural choice compared to other large cities in the UK (Birmingham, Leeds and Manchester) considering contextual developments at the time. Specifically, then-Mayor Livingstone had formalized the city's commitment to climate protection in the Energy Strategy (2004) and the Climate Change Action Plan (2007), both which included strategic statements on the intention to encourage the use of PV in the capital (such as for instance, through spatial planning policies formulated in the revised version of the London Plan (2008)). Evidence from the scoping study suggested that PV was not only rhetorically on the urban agenda, but also that a series of high profile cases were being implemented across the capital. London also presented an interesting national policy context, with commitments to small-scale renewable energy technologies, such as feature predominantly in cities, lagging behind the other potential case study countries (France, Germany and Spain).

Barcelona and Berlin were prime contenders in terms of the favourable national policy contexts at the time – Germany, in terms of featuring the first and perhaps single most successful renewable energy income reward scheme (‘feed-in’ tariff) for small scale solar power generation since 1991, and Spain with its slightly more recent (1998), but similarly generous, feed-in tariff for PV electricity. While both contexts constituted a strong national commitment to PV, in terms of urban PV the decision to commit to a Barcelonan case study was shaped by field research that took place in London in November 2008. In an interview with a knowledgeable solar energy industry analyst, he argued strongly in favour of a Spanish case study:

> I think Barcelona would be a lot more interesting than Berlin to be honest [laughs]… Frankly if I were you, I would try and change, because I think you will end up with a much more interesting story… Berlin makes no sense to me at all, frankly… Barcelona would be a fantastic story, so – but I’ll leave you to it.
> (Vice-president, *Solarbuzz,* Interview, London, November 2008)

The interviewee’s reasons convinced me that Barcelona would be a better ‘most different’ choice: it provided a climatic contrast (in terms of greater irradiation, compared to London and Paris), a rapidly changing (‘stop-go’) policy context, and ‘a lot of lessons to be learnt from it’. The choice of Barcelona was thus justified on this basis and by further by considering its relatively more dense urban morphology (compared to London/Paris), and considering the contradictory exploratory finding that PV was not being implemented in the volumes to be expected by its favourable southerly geographical location and national technology policy commitments; a puzzle that seemed promising in terms of yielding an interesting and unusual perspective on urban PV.

Finally, Paris was selected based on the impression gained from the scoping study that, despite a provocative statement of the Parisian Mayor – to make Paris the 'solar energy capital of the world' – there was little preliminary evidence of any significant installed PV capacity in the city. Moreover, while climatically speaking a less obvious choice then more southerly larger European cities – capitals such as Rome and Athens, or even within France, Marseille – the Parisian case presented a context of distinctly 'urban' interest in two important ways. On the one hand, an argument in favour of a French case study was the French feed-in tariff that rewards a much higher price per unit of electricity generated to 'building-integrated' PV systems; a factor of considerable interest in the case of urban PV. On the other hand, contrary to many other cities, the Parisian context, specifically, further constituted an extreme case in terms of the city's notoriously strict development guidelines concerning the integration of new urban elements such as new (renewable energy, and other, ICT) technologies.

In sum, while Barcelona, London and Paris were selected based on a conventional 'most different' case study strategy, it is difficult to say retrospectively whether an earlier exposure to relational comparative urbanism literatures would have significantly affected the selection of field sites. In principle, the relational turn in comparative urbanism has not criticized the selection of contrasts; and in practice scholars such as Jennifer Robinson (2011) even encourage thinking relationally across the 'incomparable', paradigmatic cases of the 'Global North' and 'Global South'; and pragmatically Barcelona, London and Paris offered themselves up as valuable case study contexts. While thus not shaping the selection of empirical cases, relational urban comparative thought did, however, substantially inform data analysis and the presentation of findings. This will be explored in more depth in Section 3.5.4. At present the chapter turns to consider how a material semiotic position informed processes of data collection; in particular with respect to what constitutes 'data' (from a material semiotic perspective), and how it was collected in the context of this thesis.

3.4 Data collection: tracing associations through time and space

As a process of inquiry rather than a methodological choice as such, case studies are not disciplinary or paradigmatically bound to specific methods of data collection or analysis – allowing (and even requiring) the combination of different sources of evidence (Hesse-Biber and Dunleavy 2011). For Yin (2003: 4), the empirical richness and complexity of case studies means that "the study cannot rely on a single data collection method but will likely need to use multiple sources of evidence”. This often translates into a strategy of ‘triangulation’ using mixed methods, such as surveys, questionnaires, interviews qualitative and quantitative indicators, and archival records. While sympathetic to the merits of combining “approaches as appropriate, while recognizing the strengths and weaknesses of each” (Ley and Mountz, 2001: 234), a material semiotic position, as adopted in this thesis, rejects the notion that evidence sources can be ‘triangulated’ to accurately capture a reality ‘out there’, independent from the researcher (Law 2003). In addition, it is wary of the performative effect such methods have, for instance in terms of reifying the ontological existence of knowledge categories that frequently guide the assembly of empirical data, as well of the singularity of complex phenomena. Both are important points in terms of the conceptual position outlined in Chapter 2. Rather than collecting data according to pre-defined categories, a material semiotic approach implies a rather different data collection procedure.

Using the notion of ‘tracing associations’, Austrin and Farnsworth (2005: 148; Serres and Latour 1995) liken a material semiotic method such as Bruno Latour’s to a type of ‘detective work’ that is concerned with “explication and unpleating, tracing and unfolding complex arrangements to reveal the implicate, unforeseen elements and practices that constitute them”. Accordingly, the method is characterised by a commitment to “tracing and tracking” (ibid.) heterogeneous association in order to make visible those intricate relations that generate complex phenomena (such as technology, agency and innovation) as ‘effects’. Rather than a data collection strategy guided by the ‘sampling’ of evidence sources this suggests “following circulations” (Bingham and Thrift 2003). As opposed to seeking the ‘representativeness’, ‘statistical significance’, or ‘randomness’ of data collected, ‘tracing associations’ is distinctly and purposefully non-random. Latour’s (2005: 12) suggestion is “to follow the actors themselves’ in order to learn with them how they establish new associations”. In other words, “what material evidence and what relations must be traced and linked” (Austrin and Farnsworth 2005: 153) is not determined according to an ‘objective’, a priori, means but is emergent from the research process itself. This effectively places the “the fieldworker’s canniness” (ibid. 157) as central to the research process. While it has been argued that such a method is empiricist, a-theoretical and naïve (Collins and Yearley 1992), the overt acknowledgement of the researcher’s centrality suggests to Austrin and Farnsworth (2005: 152) “a richness, not a poverty, of method”. The notion that collecting data already constitutes an interpretative act, is also defended by Crang (2010), and it provides scope to reflect upon the performativity of one's data collection method (Law 2003).

As a method that is fundamentally material semiotic the notion of 'tracing associations' itself is however not prescriptive of how precisely associations are to be traced, or which ones in particular matter. In early laboratory ANT studies, for instance, the tracing of associations applied to the chains of translations involved in turning observations in the lab into the 'hard facts' of science. These largely ethnographic studies involved, for instance, the immersion of the researcher into laboratory life over a period of time, enabling the study of 'science in the making'. Similarly, Callon's (1986) seminal scallop study was tied to a particular setting to understand the enrolment of different entities into the scientists' scheme. Other ANT studies of innovation however are less 'ethnographical' in the sense of adhering to a method that is sedentary, real-time and exclusively focused on the particular over the general (Hesse-Biber and Dunleavy 2011). In studies such as Latour's (1996) *Aramis, or the love of technology* or Law's (Law 2000b) reconstruction of the failure of the fighter jet, the researchers (whether the very real John Law or the fictional 'professor' and 'his student' in *Aramis*, do not study the event under investigation in 'real time' and in isolation, but physically move between settings to inquire into the relationship between their particular case to broader patterns of innovation and demise. Similar to these latter material semiotic ANT studies, this thesis is shaped by a need for a methodological register that accommodates tracing associations across time and space, across distinct actor groups and geographical contexts. Rather seeking to generate the 'texture' a traditional ethnography, a strategy of 'tracing associations' in this thesis on the emergence of urban PV implies fluid and adaptable methods that reveal events 'after the fact' and not only those 'in the making'.

At this point is it worth stating a limitation to this approach to data collection. The problem that emerges from tracing associations relates, for instance, to establishing which precisely are the relevant relations, i.e. that which "must be traced and linked so that cases can be cleared and crimes solved…?" (Austrin and Farnsworth 2005: 153)). The fieldworker's 'canniness' may be surpassed by instances where relations have become effaced, as is often thought to be the case when one deals with institutionalised settings (Callon 1991). While some such 'invisible' associations cannot be traced at all, at other times it becomes impossible to follow up every trace encountered. For instance, sometimes time simply did not permit this, and other times it would have required a radical shift in method register (for example, from face-to-face interviewees to survey questionnaires). Wary of these limitations, tracing associations is nonetheless a promising method, importantly, as it allows the researcher to remain open about the shape and quality of associations that may link humans and non-humans. In this respect, *what* precisely counts as data is very broadly construed from a material semiotic perspective. In the case of this thesis, it emerged that the main forms that the data collected took ranged from a variety of text-based sources (including visual photographs and graphs), as well as in situ face-to-face conversations, more structured interviews and the attendance at formal events (Table 1-2). In practice, the assembly of these materials fell into relatively distinct stages of data collection. Below follows an outline of the different stages of data collection with reference to what precisely was collected and by what means, as well as considerations of the limitations associated with each stage.

Table 3-2 Summary of data collected

Texts (1st Stage)				
Type	*Barcelona*	*London*	*Paris*	*Other*
Brochure	15	18	10	1
Guidance	8	20	20	1
Policy documents	20	45	14	-
Press release	39	18	12	3
Report	30	57	30	6
Other (e.g. memos, videos, database…)	19	47	30	5
TOTAL by city	**131**	**205**	**116**	**16**
In situ (2nd Stage)				
Type	*Barcelona*	*London*	*Paris*	
Face to face interview	7	9	5	
Questions by email	1	-	5	
Telephone	1	3	-	
Other	-	-	1**	
TOTAL respondents*	**11**	**13**	**13**	

*some interviews were conducted with more than one respondent

**public Q&A session

3.4.1 1st stage: gathering techniques

As has already been mentioned above, the research process began with an exploratory scoping study that was desktop-based at Durham University during the very early stages of the project.

This starting point, through an internet connection is both semi-arbitrary and a product of its time – without such a thing as the internet it would clearly not have been feasible, on the other hand, it is only semi-arbitrary in that it was instrumental in establishing a broad and wide-ranging initial connection between myself and urban PV in European cities. It involved extensive internet searches using search engines such as google (.com; .co.uk; .fr; .de; and .es) in English, French, German and Spanish to select which urban context would be investigated in depth. It used terms such as "PV", "photovoltaics", "urban photovoltaics", "solar cities" (etc) to gauge ongoing PV-related activities within and across European cities. Having selected Barcelona, London and Paris as specific urban contexts (according to a 'most different' selection criterion), I intensified the key word search and began saving electronic files that could be downloaded and saved in folder on a computer hard drive from the internet. I did not discriminate between different types of data (promotional brochures and flyers, press releases, power point slides, advocacy and technical consultancy reports, PV industry literatures, and a range of policy literatures) or any particular electronic format (pdfs, word documents, .ppt, .doc, html etc.). All documentary sources are listed in Appendix A. They are distinguished by city (Barcelona, London and Paris) and a 'general' table, ordered alphabetically and each given a unique identifier. Major policy reports are also cited in the main list of references. Throughout the thesis sources are referenced using their identifier when appearing in figures (**#X**), while in-text citations only quote the identifier if the document is not otherwise referenced in the main reference list.

The sorts of data collected during this first phase can be understood as 'texts' in the broad sense of the term. A general characteristic of texts is that they are *non-reactive* and *non-interactive*, in the way that their existence and physical content does generally not depend on, nor is altered, by the researcher or the research process (Hesse-Biber and Dunleavy 2011). From an ANT material semiotic perspective texts are important 'intermediaries' which constitute networks of communicative activities; once authored for a particular purpose and audience they may circulate between actors and different spaces without changing their shape (Callon 1991). The characteristic of authorship implies that their production is situated and as such contains (often implicitly) the values, worldviews and opinions of those who produce them. However, from a material semiotic perspective the importance of texts does not only derive from the way "we can learn about our society by investigating the material forms produced within it" (Hesse-Biber and Dunleavy 2011: 227). Importantly, texts (along with other intermediaries) are thought to perform particular sociomaterial realities through the different rhetorical forms they contain, such as linguistic argument, visual representations using photographs, semi-naturalistic depictions, graphs and figures (Law and Whitaker 1988).

Collecting texts through the internet was a straightforward process of data collection as texts were freely available, downloadable and saveable in electronic format. As it emerged, evidence of PV-related activity was relatively sparse in general and concentrated among few actors in each urban context. However, there is an inherent bias to researching using the internet, which is that only that which is made available online is captured as data. Wary of the absences created through internet searches, during the second stage of the research process I identified key connections which informed further data collection 'in situ' in Barcelona, London and Paris.

3.4.2 2nd stage: making connections

This stage was concerned with tracking those relations that seemed of particular importance for urban PV-related processes in Barcelona, London and Paris. 'Importance' was established through an exploration of the large amount of texts gathered in the previous step with respect to identifying individual actors and organisations that had emerged as central authors of intermediaries, or had been mentioned numerous times in these. This following up of associations was seen as instrumental in informing subsequent interviews 'in situ'. I made a list of these for each urban context and sent a large amount of emails. This was akin to a 'cold calling' technique, except that actors had already been pre-selected through their authorship of, or appearance in, texts. These included a diversity of actors, such as architects, engineers, policymakers, community groups, NGOs, energy agencies, industry lobby associations. I used emails to establish an initial contact and ascertain whether the organisation was in fact involved with PV and whether they would be willing to participate in the research (see Appendix C). I tailored emails to the specific organisation or actor and included an attached one-page outline of the research project and research questions, taking care to make the research relevant to their particular professional practice and experiences, as a form of building 'rapport' with a specific contact.

From a large amount of organisations contacted only a minority expressed interest in taking part in the research project. The notion of 'access' is frequently noted in literatures on methods as an important limitation of research processes (Parry 1998). This is in particular the case when researching so-called ‘elites’ (Cormode and Hughes 1999). The researcher of elites is described as “a supplicant… dependent on the co-operation of a relatively small number of people with specialized knowledge” (Cormode and Hughes 1999: 299). This understanding is useful to the to understand difficulties of encountered at this stage of the data collection process. The diversity of professional groups I contacted shared in common that they were generally busy people and had little time that could be set aside for meeting with a researcher. In addition, some did not think that my research concerned them (despite my best attempts at building rapport). Even in cases where I had an ‘inside contact’, someone personally acquainted with those I sought to access, this did not necessarily result in being granted an interview. Often I did not receive any replies and at other times a ‘gatekeeper’ (Horwood and Moon 2003) would prevent me from gaining access. Parry (1999: 2160) notes that “chance, luck and intuition” plays a crucial part in successfully accessing elite networks – in practice, being unsuccessful in gaining access to some actors that appeared as important from their authorship or appearance in intermediaries did restrict my attempts at following associations.

From a total of 127 emails I sent out I managed to set up a total of 21 interviews to take place in Barcelona, London and Paris. In addition, once in situ research stays were finalised, I searched for any PV-related events taking place during that time in the three cities (and identified a 4 which I attended). The in situ stage of data collection and its limitations are explored in the next section.

3.4.3 3rd stage: following up associations in situ

I followed formal departmental ethics and health and safety procedures prior to commencing three periods of field research in London (November-December 2008), Barcelona (March-April 2009) and Paris (May-June 2009). During these stays I conducted interviews (see Table 3-2) in English, French and (Castilian) Spanish with over 20 different organisations and I attended 4 events. Both interviews and events were recorded and later transcribed manually using a transcription software, verbatim, in the original language (English, French or Spanish) of the recording, and saved in the relevant case study folders. The following paragraphs outline how I prepared and conducted interviews and event observation.

Interviews

Face-to-face interviews with specific actors were deemed necessary to further trace those technological relations which emerged as particularly important from an extensive review of textual sources. The interview method is one of the most widely used forms of data collection (Mason 2006; Noy 2009), however across different methodological positions the significance of interview materials varies (Abell et al. 2006). From a realist perspective interviews “allow the words of the respondent, and his or her experiences and perspectives, to shine through” (Hesse-Biber and Dunleavy 2011: 102). However, a social constructivist position would stress treat the interview as a “local accomplishment” (Silverman 2001: 104) which is not an ‘objective’ account of interviewees’ reality but rather constitutes a situated event in which meaning is constructed interactively between researcher and interviewee. A material semiotic perspective on interviews (although this has not been explicitly articulated) would go beyond the constructivist focus on inter-subjective meaning making in understanding the interview as itself generative of a particular sociomaterial reality. In particular, it would suggest that it is part of the performative reality-making of the research process. The distinction between a constructivist and material semiotic perspective is that in the latter the object under investigation is itself being performed through the interview, and it may be the case that the interview event has consequences beyond its situatedness.

In each case I clarified the conditions of the interview by sending interviewees a formal ‘consent form’ prior to the interview which guaranteed interviewees anonymity of name but not of their organisation, and provided for the possibility to go ‘off record’ at any time they desired to do so. A blank consent form was also taken to the interview on the day and signed by respondents (see Appendix D). As was previously stated, *who* precisely was interviewed emerged inductively through the research process and as a result a very heterogeneous set of actors were interviewed. However, they were mostly male (with few exceptions), between 30-50 years old, from professional backgrounds in technical professions (engineers, architects, planners) and policy, but also included activists, academics, and employees of non-profit organisations such as energy agencies and environmental charities (see Appendix B). The heterogeneity of interviewees meant that the sites of interview differed (e.g. meeting rooms, office cubicles, a rooftop terrace, a PV laboratory, a PV training centre filled with panels, Starbucks). I understood these as providing me with an interesting perspective on the ‘where’ question of innovation (Law and Mol 2001). As

Elwood and Martin (Elwood and Martin 2000: 649) note, attentiveness to the "social geography of a place… can offer new insights with respect to research questions, help researchers understand and interpret interview material, and highlight ethical considerations in the research process".

Practically every interview necessitated a careful planning in terms of dress, gauging how I was going to approach the particular interviewee and how to prepare the substantive part of the interview. Accordingly for example, for interviews with London-based policymakers and industry actors I chose a more formal dress style, while at the other end of the spectrum I wore jeans and sandals for an interview with Barcelona-based activists. Some interviewees were used to being interviewed, while others weren't – 'will you be asking really hard questions?' (Architect, London). Some were familiar with the social science research practice, while others weren't – ('what do you mean by a conceptual framework?' (Engineer, Barcelona). Some wished to go off the record for particular statements ('don't quote me on that') or distinguished their personal opinion from that of their organisation ('that's my personal view, not a [organisation's name] stance'). I naturally approached each interview with a set of expectations, while trying to remain open to what I would encounter in situ. I began each interview with explaining what I was doing, why and how I would structure our conversation. I opted for a 'semi-structured' form of interview which revolved around a set of general themes relating to the research questions as well as themes specifically tailored to each interviewee (taking the material form of a one-sided A4 'interview guides' that I took into the interviews). The general approach taken was to let the conversation flow as much as possible, as a reflection of ANT scholars' suggestion to aim to understand how actors themselves 'freely' associate different places, times, materials, technologies and people (Latour 1996; Callon 1986b). I did, however, re-direct the conversation when I felt we had drifted too far from the research questions and made sure all points had been covered (in no particular order). At times I asked for clarification of what actors understood by particular concepts (e.g. 'technical barriers', 'them', 'people') and concluded each in interview with asking whether the interviewee would like to add anything.

As a method of data collection, interviews permitted me to further follow up on associations that I deemed important from having explored textual intermediaries of communication. However, the in situ and dynamic nature of face-to-face conversations raises several issues with respect to placing the interview as a sociomaterial performance of the object of investigation. Unlike texts, the interview could be construed as performing a type of datum about the object investigated that is 'artificial' in the sense that, from a material semiotic perspective, it would be understood as sociomaterially part of research practice strictly speaking (as opposed to actors immediate world-building activities). On the other hand, by agreeing to be interviewed, the interview could be understood as itself part of actors' purposeful activities. Either way, what is generated in the interview is dependent on several factors worthy of mentioning. In the first instance, interview guides inevitable contain important decisions about what is perceived as important to the researcher. While my intention was to enable an open-ended conversation with little pre-given structure, the interview guide nonetheless stated that particular issues needed to be covered, while others might emerge through conversation. While absences are created by omission, on the other hand the interviewer can exclude by not following up and probing particular statements. Finally, Parry (1998) notes that interviewing elites is accompanied with issues of power asymmetries and insider-outsider dynamics. I experienced this, for instance, when I waited for an important interviewee for over an hour in the corridor of Barcelonan university on one occasion. However, during the interview itself neither asymmetries nor outsider dynamics were clear cut across interviews and cities. In some ways I was always an 'outsider' – based, for instance, on nationality (perceived as foreign), age (younger), profession (social scientist compared to most interviewees with technical backgrounds), gender (female compared to the vast majority of male interviewees). However, other aspects, such as good knowledge about PV, frequently a shared sense of purpose in understanding the barriers to PV were used to emphasize commonalities.

Event observation

While interviews were the primary reason for scheduling in situ stays in Barcelona, London and Paris, I also attended a series of events during my time in London and Paris. In Barcelona no relevant (PV/renewable/urban energy) events were taking place at the time of my stay (a Barcelona-based interviewee explained that this was because PV-related activities in Barcelona had 'run out of steam'). As I had not factored event attendance as an explicit data collection method, my approach to events was much less systematic than tracing associations through texts and interviews. However, in general events may be treated as another form of sociomaterial enactment of the object of study from a material semiotic perspective. Like texts, they are 'authored' (or rather, organised) by particular actors and for specific purposes. However, unlike texts and more akin to interviews they last a limited amount of time for the duration of which they enable direct interchanges between different actors, in particular locations. Unlike interviews, however, I did not play an important role in setting them up. Nonetheless, the means by which I collected events as data is important in terms of performing events as a sociomaterial practice through which the object of study is enacted.

My attendance at events can be understood as a form of ‘participant observation’, albeit one in which my participation was limited. I can be situated as somewhere between taking a ‘fly on the wall’ and ‘observer as participant’ (Watt and Jones 2010) position (although it should be noted that this was not a conscious choice at the time). While the former refers to a form of observation that is ‘unobtrusive’ (through attempting the absolute separation of researcher and the observed), the latter allows for a degree of interaction with the observed. Primarily, I used events such as the Westminster Energy, Environment and Transport Forum keynote seminar on the ‘UK’s Renewable Energy Strategy’, the ‘Building a Low Carbon Future’ event (Deutsche Bank and German Embassy in London), and the ‘Conférence des Maires et élus pour le solaire’ to make potential interview contacts through ‘networking’. I voice recorded the events I attended and took notes of statements that ‘struck me’ (Saldaña 2009) on a separate sheet of paper along with the hour/minute/second at which they occurred on the recording. Some, but not all, voice recordings were subsequently transcribed. I also paid attention to what Elwood and Martin (2000: 649) call the “micro-geographies” of events: “the people, activities, and interactions that constitute these spaces… participants’ varying positions, roles and identities in different sites”. This was, however, not accompanied by an in-depth reflection in terms of how my presence might be “disturbing the situation” (Collins 1984: 55).

As a result of a rather unsystematic commitment to events as data sources, the importance of events as sources of data that I could analyse mostly occurred to me ex post facto. Importantly, my event attendance relied heavily upon being able to gain access to the event (at no, or a reasonable, cost) – which was an obstacle at several occasions where events were organised by industry actors at elevated ‘the-cost-of-networking’ prices.

3.4.4 4th stage: keeping in touch

The final stage of data collection can be considered a stage that began in each case following in situ stays. Mainly, it aimed at staying abreast of PV-related developments, considering the fast-paced nature of evolutions in the industry and, in particular, the cases of London and Paris). This involved 'monitoring from afar', including following the publication of press releases (*Solarbuzz*, *Euractiv*), mailing lists, keeping up to speed with industry literatures (such as *Sun&Wind Energy*, *Solar Today* and *Renewable Energy World*) and keeping in touch via email with some of my interviewees for updates.

As a largely ongoing stage in parallel of data analysis and 'writing up' important choices had to be made in terms of how the data collected was to be handled in terms of informing analysis and the arguments of the empirical chapters. The choice was made to include seminal events (such as new policies and policy reform), but not events that were deemed more marginal judging from the email updates sent by interviewees). With respect to the former, considering the importance of these events, and the availability of substantial material about them it seemed inappropriate to place an artificial temporal cut-off point to data collection; it did however mean that these events were not followed up in a face-to-face manner.

3.5 A material-semiotic data analysis

Having outlined the four broad stages of data collection, the chapter now turns to outlining how a material semiotic data analysis was conducted. While data collection necessarily already constitutes a way of ordering data that is far from 'innocent' (Crang 2010), the notion of data *analysis* refers to a more explicit act; that of turning "what can be voluminous data into understandable and insightful analysis… in a meaningful way" (Liamputtong 2009: 133). Neither the emerging relational comparative urbanism literatures, nor material semiotics as developed by actor-network and 'after' scholarship is explicitly prescriptive of particular forms and processes of data analysis. Nonetheless, material semiotics concepts of relationality, material heterogeneity, performativity and multiplicity (see section 2.4) provide general principles from which a material semiotic analysis can be operationalised for the purpose of this thesis. Principally, a relational analysis (whether urban or explicitly grounded in material semiotics) implies avoiding imposing deep-structuring analytical categories upon the data collected) and focusing instead on the relational constitution of complex phenomena. As Gillian Hart suggests:

> Instead of taking as pre-given objects, events, places and identities… start with the question of how they are formed in relation to one another.
> (Hart 2002: 14-15; cited in Ward 2010: 480)

The kind of materialist relationality advocated by material semiotics suggests that analysis ought to be attuned to how different elements (humans of different professions and occupations, technologies and other materials) are associated to one another, both discursively as well as materially in practice. Further, performativity implies a 'praxiographical' analysis which is taken by Jensen (Jensen 2004: 10) to refer to "engagements with actual work practices". Multiplicity, in turn, constitutes a recognition of the simultaneity of co-existing sociomaterial practices. Crucially, the combined principles of relationality, performativity, materiality and multiplicity enable an analysis that is faithful to the kind of reflexivity advocated by material semiotic scholars, as it acknowledges the "unavoidably fabricated nature of the accounts that finally emerge" (Austrin and Farnsworth 2005: 147): as such, academic practice is understood as itself generative of particular versions of the (sociomaterial) reality of the object of investigation (and as such, may well have potentially transformative effects).

Taken together, these four principles in the context of the this thesis direct attention towards inquiring into the *relationship* between different sociomaterial practices, by analysing data collected about these. However, despite providing useful general principles, little guidance is available on how to translate a conceptual commitment to relationality, performativity, materiality and multiplicity into research practice. In this context, I developed my own translation of material semiotics into several cycles of data analytical procedures, which I rooted in existing literatures on qualitative methods in the social sciences. However, developing an analysis process that is true to material semiotic principles was neither straightforward nor smooth in practice. There were several dead ends and moments of uncertainty. It is not the intention to gloss over these, however for the purpose of clarity my conversion of a material semiotics into practice is presented in four distinct analytical 'cycles': 'exploratory coding', 'story-ing', 'sociomaterial multiplicity' and 'explicit comparison'. These are discussed below in turn, each time blending well-established literatures with material semiotic principles. Difficulties that arose in the process of converting material semiotics in theory into analysis are flagged as they arose over the course of the research.

3.5.1 1st cycle: exploratory coding

The first step of analysis focused on becoming familiar with the vast amount of data gathered. This was done by 'coding' a selection of texts and interviews on an 'exploratory' basis. Coding is frequently used as a first step in data analysis to "define what the data is about" (Charmaz 2006: 134). According to Saldaña (2009: 8) coding is "an exploratory problem-solving technique without specific formulas to follow". Coding is a way of 'filtering' data in relation to research questions, and as such it is a technique that can be grounded in different methodological positions rather than associated exclusively with a particular social science paradigm. Specifically, a code is a "word or short phrase" that assigns to an extract of text or picture an "essence-capturing, and/or evocative attribute" (Saldaña 2009: 3). Depending on one's methodological position one may code data using inductive or deductive codes, i.e. codes that are generated from the data itself, through asking "what strikes me?" (Liamputtong 2009: 134; Saldaña 2009), or codes designed prior to entering into contact with the data. Whichever is chosen, Saldaña (2009: 4) emphasises that "coding is not a precise science; it's primarily an interpretive act". Several authors distinguish between the researchers own codes and 'in vivo' codes which are "terms and names that the participants actually use in their narratives" (Liamputtong 2009: 134).

Here I will use an example to illustrate how I applied coding using an open source qualitative data analysis (QDA) software, Weft QDA (Figure 3.2). Due to my use of coding for exploratory purposes I attempted to keep my coding strategy simple: I chose to analyse the urban contexts in separate Weft documents to avoid working across different languages (although I did code in Castilian Spanish and Catalan in the case of Barcelona), I chose to only code texts (as opposed to including visual media) and I uploaded a selection as opposed to the totality of texts collected in each case study. In terms of codes, I used a combination of inductive 'in vivo' and deductive higher level codes to explore a selected number of texts from each urban context. Deductive codes were used as a broad overarching frame for organising subsequently emerging inductive codes. The former derived from the research questions of the thesis, while the latter were added into the deductive framework as different parts of the texts 'struck me' upon reading them; for instance if I thought they were unusual, if there were repetitive patterns across texts. In the example taken from London in Figure 3.2 the deductive frame consists of 'rationale' (for using PV) and 'actors' (roles identified with respect to PV). Inductively a range of codes were added in the process of coding ('an energy generator', 'reduce carbon emissions' etc. and 'technical advice', 'leadership', 'finance/investment' etc.). The screenshot in Fig 3.2 further illustrates how Weft enables to then draw together different coded passages from different documents that have been coded using the same codes (e.g. on PV's carbon emission reduction potential, from a Greater London Authority Press release, a London South Bank University Consultancy report and a London Assembly publication).

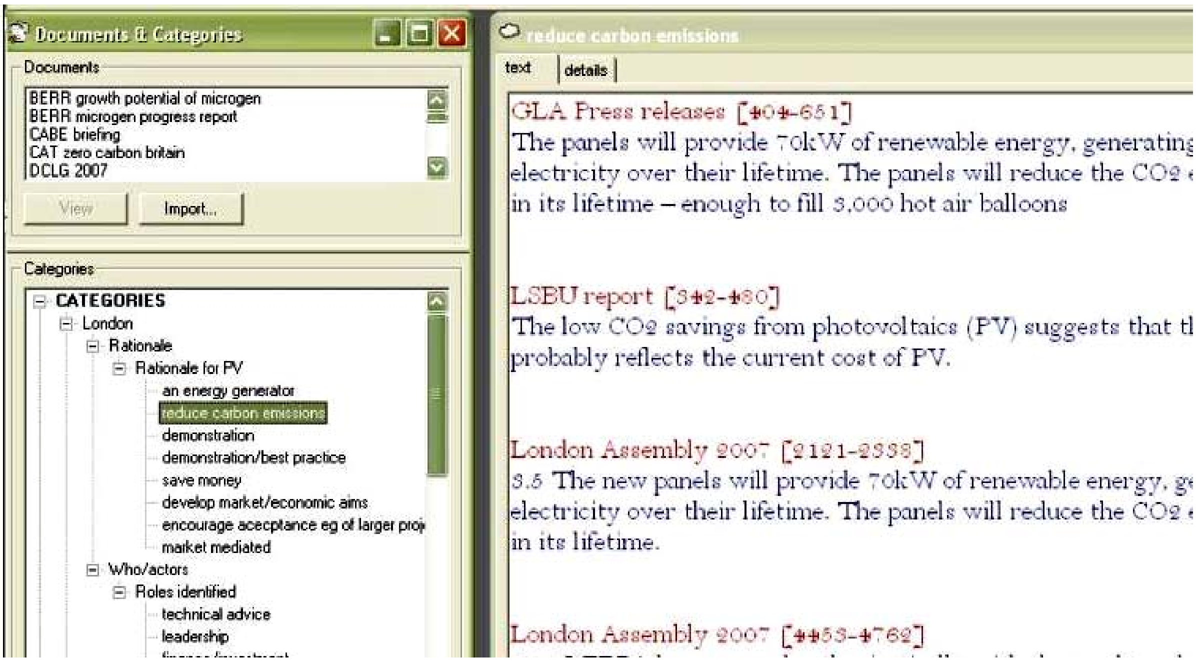

Figure 3.2 Exploratory coding using Weft QDA

Above anything, coding served as a way of getting acquainted with the data on a systematic basis to make an exploratory start at analysis. The codes used were descriptive, often using in vivo language. While the same deductive codes were used for exploratory coding of the three urban contexts, inductive codes differed significantly across cases; on the whole there was much repetition and only limited attempts were made at merging codes or moving to a higher level of analysis using coding alone.

While useful for identifying and generating 'themes' (emergent patterns of important actors, features, events etc) a linguistic analysis using codes was not enabling me to pursue a material semiotic analysis as outlined above; according to principles of relationality, materiality, performativity and multiplicity. Therefore, rather than relying on coding alone I chose to use coding as a stepping stone for the second and third cycles of analysis described below. While the latter develops an analytical technique for capturing sociomaterial multiplicity, the former begins to add depth to a material semiotic analysis in terms of bringing different sources of evidence (and the practices, events, spaces and technologies they perform) together into a temporal sequence.

3.5.2 2nd cycle: story-ing

The second cycle of data analysis was concerned with gaining an understanding of the chronological sequence of the data collected. This was not taken to impute causality, as is often typical of a 'narrative analysis' applied to individuals' life stories (Gibbs 2007). Rather, I term this cycle 'story-ing' following Franzosi's (1998: 520) understanding of 'stories' as referring to "a skeletal description of the fundamental events in their… chronological order". Importantly, this involved stepping outside of the purely linguistic dimension of the content of texts analysed in the previous cycle. The aim was to construct timelines of innovation in photovoltaics across the different urban contexts according to ANT scholar Callon's (1986b) principle of 'free association'. By this Callon suggests an analysis that is attentive to the way in which different entities (places, materials, technologies) are 'freely' associated with one another in actors' "world-building" activities (Jensen 2004; Callon 1986a) – as opposed to constructing meaning through treating heterogeneous entities as ontologically distinct. The aim was to arrive at a 'seamless web' type of timeline which is geared towards identifying the temporal distribution of key features in innovative processes, whether these are particular events, actors, documents, policies, PV systems, or other. Austrin and Farnsworth's (2005: 155) metaphor of the researcher as 'detective' is useful here:

> the detective who, arriving by definition after the event (or crime), also has to establish not just who committed it, but exactly how… this involves a meticulous 'microprocessing of the facts' – a sifting through the jumble of clues that may enable a reconstruction of the original sequence of events.

Importantly, rather than imposing my interpretation of what *I* might think is important in innovative processes (for example, 'national policy frameworks') a material semiotic analysis implies paying attention to "the way in which the actors analyze the society which surrounds them" (Callon 1986b: 199). Story-ing from actors' own perspectives (as contained in texts, performed in interviews and events) resulted in heterogeneous timelines that consisted of events, actors, documents, policies, PV systems. An extract from the timeline that was composed for Paris is reproduced in Table 3-3. It only shows a selection of the temporally organised sequence of (heterogeneous) 'key moments' in the far left column according to when, what, where and why questions. For instance, the 2001 coming into force of the national feed-in tariff was deemed of significance by the quoted interviewee because it was a step change in terms of acknowledging PV's formal legality before the law.

Table 3-3 Constructing timelines through story-ing (2nd analytical cycle)

When?	What?	Where?	Why?
…			
2001 – Jan	Feed-in tariff	National	"the first tariff was as if to say, 'ok, photovoltaics has the right to exist. But we won't *really* encourage it'" (Director at *CLER*, May 2009, Paris)
…			
2001 Sep	*CLER* PV installation	Parisian Suburb	I remember how *CLER* invited the journalists from *TF1* [French TV channel] to show off the installation and to expose the 'scandal of non-connection'. And then, *hop!* The next day it was connected, more or less… Nowadays, grid connection is much easier. (Energy Advisor at *IDEMU*, Paris, May 2009)
…			
2006	*Plan Climat*	Paris	Basically, there are incoherences between the *PLU* and the *Plan Climat*. So, in the *Plan Climat* it is stated that solar panels *need* to be installed, in the *PLU* we are told that we are not allowed to install solar panels [laughs] (Energy Advisor at *PASU*, May 2009, Paris)
…			
2008	Electoral statement on 200,000m^2		It's ludicrous from the outside… but, one of the difficulties is to get it into peoples' heads, mentalities, that Paris has a problem of *patrimoine*, it prevents her from moving with the times. (Director at *CLER*, May 2009, Paris)

Crucially, while the timelines I created for Barcelona, London and Paris are still to a degree my own situated accounts of 'key moments', by allowing for what actors' themselves deemed important events, actors, systems, policies (etc.) to become freely juxtaposed in a temporal sequence I sought to avoid a meta-narration of events that is either 'above' or removed from actors' realities. In particular, it is materially heterogeneous in the sense that it does not discriminate what counts as 'key' – in the example from Paris one is policy, a PV installation, a strategic document, an electoral statement and an entire reform process that are singled out as important 'moments'.

What begins to happen in this 2nd analytical cycle is the blending of heterogeneous materials, actors, times and places into a 'seamless web' (Hughes 1986) of innovation. While the 2nd cycle is concerned with establishing an approximate chronology of occurrences, the 3rd cycle is concerned with generating an analysis that is sensitive to the multiplicity of this heterogeneous sociomateriality.

3.5.3 3rd cycle: sociomaterial multiplicity

> …we were trying to study something that was turning out to be a moving target. Actually a shape-shifting target too… Maybe we were dealing with something that wasn't definite. That didn't have a single form.
> (Law 2003: 4-5)

Having become familiar with the thematic content of the data and having developed an understanding of the chronology in which heterogeneous entities became involved and came to matter in innovative processes, the following step was to focus on understanding the 'sociomaterial multiplicity' of such key moments. It involved moving from analysing different data sources as discrete entities towards acknowledging their interconnection in constituting innovation in urban PV. As such, texts, interviews and events should be thought of as sociomaterial forms of representational practice which work in different ways to perform the reality of innovation. The issue at stake can be illustrated using Latour and Woolgar's (1979) *Laboratory Life*. The problem is that retrospective accounts or anecdotes of past events by scientists (and in my case through textual intermediaries and interviews) efface "exactly how the process of innovation or discovery actually took place" (Austrin and Farnsworth 2005: 155). For Austrin and Farnsworth (ibid.) retrospective accounts "invoke the very mysteries of creative innovation which [the researcher is] intent on demystifying". The analytical implication from a material semiotic position is to trace particular pivotal moments as effects that take on their stability ex post facto. Critical to revealing multiplicity is to interrogate their seeming coherence and singularity by attending to the relationship between different actors' realities and interpretations of 'key' events, actors and materials. For Mol (2002: 4-5) analysis ought to focus on how seemingly singular and potentially coherent 'version of events' are generated in and through the relationship between different, heterogeneous sociomaterialities:

> Attending to the multiplicity of reality opens up the possibility of studying this remarkable achievement… the objects handled in practice are not the same from one site to another: so how does the coordination between such objects proceed? How do different objects that go under a single name avoid clashes and explosive confrontations? And might it be that even if there are tensions between them, various versions of an object sometimes depend on one another?

The consequence of the notion of sociomaterial multiplicity is literally that "reality multiplies" (Mol 2002: 5). Contrary to social constructivist accounts of *interpretative* multiplicity (i.e. that different actors attach different meanings to the same object or technology), material semiotics suggests that 'world-building' activities are just that: practices that produce actual versions of reality, with very material consequences. Such a proposition is powerful in enabling an analysis that has scope to accommodate potentially multiple realities of PV across different sites of practice.

An example from London is useful to illustrate how a commitment to sociomaterial multiplicity translates into practical analysis. The photovoltaic system at London's City Hall was one such 'key moment' of innovation in urban PV in London, as identified by several interviewees and in numerous documents. In Figure 3.4 four distinct data sources are juxtaposed, some which blend photographic visuals with text. Crucially, all these serve to present a rather different reality of the PV system; as the Greater London Authority positions the system as an example to follow, the systems' architects as an architectural icon, a very difficult project and learning opportunity by the engineer involved in the project and a waste of tax payers money from the perspective of a community protest website. Which one is it? Crucially, through analysing different data sources not in isolation from one another but in concert, a rich picture emerges of a technological story that "cannot be narrated smoothly from a single location (Law and Singleton 2003: 11). Through the juxtaposition of these different sociomaterial forms the system at City Hall is revealed as multiple in its reality (e.g. a feat of architecture, a symbol of urban leadership, a waste of

"…we hope that City Hall will act as an inspiration designing sustainable buildings in our capital"
(City Hall Building Integrated PV System, *LCCA* 2007; **#L105**)


London SE1 > News

Solar panels at City Hall - are they worth the money?

Thursday 6 March 2008 London SE1 website team

City Hall now has a custom-designed £540,000 photovoltaic system - but it only provides 1.5 per cent of the building's daily electricity requirement even on the brightest day.

Solar panels at City Hall – are they worth the money?
City Hall now has a custom-designed £540,000 photovoltaic system – but it only provides 1.5 per cent of the building's daily electricity requirements even on the brightest day.
(http://www.london-se1.co.uk/news/view/3176; **#L126**)

"City Hall is one of the capital's most symbolically important new projects…it expresses the transparency and accessibility of the democratic process and demonstrates the potential for a sustainable, virtually non-polluting public building."
(http://www.fosterandpartners.com/Projects/1027/Default.aspx; **#L50**)

…a very difficult project to do, politically, technically, and everything else…there were great many partners involved in the building…so there were about 30 bodies that had to be consulted to get that project off the ground and the pre-project consultation took longer than the project itself. We spent 18 months talking to 30 companies, getting their agreements to do the works before going ahead and doing it, which took us only 6 months last summer.
(Interview, Engineer, *LCCA*, November 2008, London)

Figure 3.3 Juxtaposing sociomaterial multiplicity (3rd cycle)

taxpayers' money). In other words, from a material semiotic perspective not the case that different actors offer mere perspectives or interpretation of a phenomenon (such as the system). Rather, a PV system such as this one comes to embody and seal into it different processes and ordering strategies such that it is the material nexus around which the ontologically multiple reality of innovation can be explored: planning committees, architecture firms, politicians in opposition, websites, and community activists each perform a particular reality of what urban photovoltaics is (and ought to be) in London. World-building practices of project delivery (and the silent others which cooperated, but become invisible once the system is in place), protest and cooperation constitute the system at City Hall, drawing attention to the ways in which PV becomes tied into questions concerning, for instance the nature and purpose of technology, its role in urban change, capacities and modus operandi of different actors and the politics shaping their associations with one another. From this approach to capturing sociomaterial multiplicity, the final cycle of analysis now moves to mobilising comparison as an explicit strategy for analysis.

3.5.4 4th cycle: explicit comparison of key moments

Through an engagement with an emerging body of scholarship on a ‘relational’ form of comparative urbanism (Ward 2010; Robinson 2011; McFarlane 2010; Castree 2005), mostly published after fieldwork and parts of data analysis had already concluded, it gradually became evident to me that framing the research as multiple case studies of three ‘most different’ urban ‘contexts’ (see Section 3.3.1) was in fact inconsistent the notion of relationality characteristic of a material semiotics. What relationality meant for studying cities was being developed at the time of research by a set of urban scholars who, taken together, can be seen as providing the early beginnings of a new approach to comparative urbanism. They critique conventional approaches to comparing cities for lacking a ‘systematic’ framework (Kantor and Savitch 2005) and reflexivity concerning the performative effect of their implicit methodological assumptions and research methods which tend to reproduce the ‘city’ as a territorially or socio-culturally bounded entity that is amenable to different types of (‘individualizing’, ‘universalizing’, ‘encompassing’ or ‘variation-finding’) comparisons (Robinson 2011). Instead, from a relational understanding of the urban isolating ‘independent variables’ as explanatory causes is not possible (Robinson 2011). Seemingly ‘contextual’ factors (such as national institutional frameworks or levels of economic development) are understood as themselves constituted “through interrelations between objects, events, places and identities” (Hart 2002: 14; cited in Ward 2010: 480).

As such, a relational comparison implied a fundamental rethinking of the nature of comparison in the context of this thesis. It required moving beyond “searching for similarities and differences between two [or, indeed three!] mutually exclusive contexts” (Ward 2010: 480). Rather than being exclusively an activity of ‘comparing and contrasting’ separate instances of a phenomenon (e.g.

innovation in PV in different urban contexts) relational comparison is concerned with understanding intelligible similarities and differences as *effects*, rather than taking these as existing in a relationship of exteriority to one another. Comparison thus becomes understood as a mode of inquiry which is geared towards an analysis “where the *effects* of difference appear” (Haraway 1999: 320; original emphasis). On the one hand, this implies a rejection of an absolute and *a priori* separation of the research into three distinct ‘case studies’. On the other, comparison thus construed suggests that difference and similarity do not precede but are themselves emergent from the analytical juxtaposition of patterns of relations. In this manner, by letting comparison unfold at the relational level, I attempted to defer making a priori decisions about which particular relations emerge as meaningful.

The way in which comparison was carried out is best illustrated by means of an example. The previous cycle explored the juxtaposition of different data sources of one single ‘key moment’ (the PV system at London’s City Hall). Here in Figure 3.5 this system is juxtaposed with another, the PV system on the terrace of *Fundación Tierra*, a Barcelona-based non-profit organisation. Despite being quite obviously very different systems, both emerged as key moments in innovation in urban PV. To understand their significance, one strategy would be to approach comparison of these two systems according to predefined notions of what is worthy of comparison – e.g. climate, or national context. A second strategy is to explore their respective sociomaterial multiplicities, as in the previous step, and place these alongside one another. As a result, several layers of comparison are opened up: there is the architectural, the climatic, and national support schemes, actors’ motivations, their resources, and so forth. Crucially, rather than then transposing what I found to matter in one setting onto the next, I carried over the same openness to comparing other sets of key moments – whatever shape these took, and to wherever tracing their associations led me.

On the whole, thus, at present the emerging relational comparison literature says rather little about how one might make practicable a relational comparison. As such, the approach to comparison outlined here is just one way through which currently rather general ideas might be translated into practice. Admittedly, it is experimental and certainly not without limitations. However it does build on one key insight from the literature; which is to harness the notion that comparison is inherent to how meaning is built (McFarlane 2010) – here, it is made explicit, with the result of avoiding imposing parameters upon analysis. While existing approaches in urban studies have tended to be 'categorical', working through ideal types (Jessop 2002: 460), this has resulted in often descriptive accounts of geographical difference between different 'contexts' (e.g. Lorrain 2005; Tilly 1984; Castree 2005). Here in contrast, comparison works on many levels, as it is rejected that there are inherently bounded 'contexts' that could be compared. However, when features of interest emerge – whichever shape these may take – then it may become relevant to compare features such as 'climate', 'urban morphology', 'national policy' etc, depending on what is being asked of the data. Thus, treating different 'contexts' not as different in kind prior to analysis is promising for generating what Bingham and Thrift (2003: 229) describe as "a sense of a world of partial connection in which all kinds of constantly shifting spaces can co-exist, overlap and hybridise, move together, move apart".

1 2

Figure 3.4 Explicit comparison (4th cylcle)

Juxtaposing key moments: the PV systems at City Hall and *Fundación Tierra*'s terrace shading installation.

(Source: [1]*Solar panels at City Hall - are they worth the money?*, London SE1. **#L126**; [2]Primera instal·lació fotovoltaica connectada a la xarxa acollint-se al RD 2818/1998, Ajuntament de Barcelona. **#B19**)

3.6 Presentation of findings

Prior to delving into this thesis analysis of innovation in urban PV as outlined above, this section details how the findings of the research are presented in Chapters 4-6. A conventional comparative study would perhaps structure the findings according to geography, dedicating one chapter per geographical context and draw these together in only one strictly speaking (that is, explicitly) 'comparative' chapter. This way of presenting the analysis was rejected as an explicit acknowledgement of the relational turn in current comparative urban studies, because such a structure would be incompatible with the sort of relational comparison that inquires not only into similarity and difference *between* contexts, but also takes into account process *within* and *across* cities. Particularly, given this thesis' research questions – concerned with the evidence, opportunities and challenges of innovation in urban European PV – the centre of gravity of the analysis lies primarily at the *intersection* of parallel innovative processes in Barcelona, London and Paris. Therefore, to capture the essence of the research questions (see Chapter 1) the findings are presented around material semiotic concepts that emerged during the research process (see Chapter 2, especially section 2.5), which constitute my original interpretation of material semiotic implications for an analysis to innovation in urban technology. Such an intertwinement of conceptualisation with the analytical process is more common in overtly 'grounded' methodologies (Barnes 1996; Benoliel 1996; Strauss and Corbin 1990) – and like these, a material semiotic methodology is unfolding and iterative, moving between 'theory' and 'field', description and analysis, whilst deeming such distinctions largely arbitrary. Even more far-reaching, thus, adhering to a material semiotic methodology also means deeming artificial the separation between the processes of knowing and understanding, of theory-building and empirical evidence. It requires admitting that knowledge creation is emergent from the mutual co-constitution of concept and observation; and is thoroughly thus 'onto-epistemological' (Barad 2007).

The implication is that, inquiring into the questions each chapter asks, the analysis presented in Chapters 4-6 blends findings from across the three cities, Barcelona, London and Paris, into one another. Rather than upholding a strict geographical separation, instances from across the cities are discussed in a 'flat' manner through the different material semiotic concepts developed in Section 2.5. Such a choice was made to mobilise the general as an entry point into understanding the particular.

The presentation of instances, or 'vignettes', using material semiotic concepts of innovation suggests that geographical context matters for innovation in unanticipated ways when one takes up a a relational understanding of space. For instance, Chapter 4 inquires into the 'utopical' nature of urban PV technology and reveals the technology to be multiply enacted as a means for a range of different ends in parallel and commensurate ways across Barcelona, London and Paris. Through this exploration the chapter attends to both the general aspects as well as the idiosyncratic aspects of the technology's place-specific constitution. It is, however, wary of assuming that geography is necessarily the greatest determinant of the nature of innovative processes. While attuned to the particularities of the complex unfolding social, material, spatial and temporal fabric of innovation in urban PV in each city, the analysis is guided by an interest in the general means, motivations, challenges and effects of innovation. As a material semiotic analysis, findings about the general character of innovation only take shape through the particular instances of urban PV in Barcelona, London and Paris.

3.7 Conclusion

Law and Urry (2004: 396) ask,

> If methods help to make the realities they describe, then we are faced with the question: which realities might we try to enact?

The answer that this chapter has developed is informed by an 'ethico-onto-epistemological' (Barad 2007) position. This means that, instead of a "self-referential glance back at one self" (Barad 2007: 88), as a researcher, one participates, along with the actors researched, in defining and re-defining the nature, shape and texture, contours and boundaries, of the object under investigation. In this respect, this chapter has sought to be accountable and transparent concerning the choices that were made over the course of the research. This chapter outlined how a conceptual material semiotic position was translated into research design, data collection and analysis. For this, the chapter has drawn on compatible literatures on research methods from human geography and literatures on social science research methods more generally. The chapter developed a commitment to capturing the dynamic nature of innovation, on the one hand, and the relational interconnection of innovative processes within, across, and beyond the urban areas investigated. This implies the juxtaposition of different evidence sources and interrogating their relationship. Neither are texts, interviews and events treated as self-contained entities, nor crucially is it presumed that there is a single (sociomaterial) version of events. The intention is to be attentive to the multiplicity not of *perspectives* but of *sociomaterial realities*. Implied is a rejection of simply reifying ‘macro’ phenomena (Castree 2005), such as a progressively ‘evolutionary’ character of innovation that takes place in niches, regimes and landscapes. It is further, following Pyke et al. (2003), an understanding of the research process as much messier than ‘going out and doing research’ followed by ‘writing up’.

Importantly, a material semiotic research strategy enables findings to be presented in a way that strategically juxtaposes and aligns different elements and instances across time and space; to generate insight into the dynamics of innovation in urban PV in general and each particular city. The approach transcends a purely geographical and chronological account of innovation and generates a targeted commentary concerning specific aspects of innovation. In Chapters 4-6 this approach is used to blur three geographical contexts into a broader process of ‘innovation in urban PV’. Chapter 4, for instance, questioning the singularity of the technology’s reality, pulls apart aspirations, means and strategies of innovation to finally reconstruct the emergence of PV in different cities. Chapter 5 mobilises this vignette approach to demonstrate the benefits of attending to innovators’ own experiences innovating in order to understand how the conditions of what is already in place in any particular location endogenously shapes the spatial quality and chronology of innovative processes. Finally, Chapter 6 explores urban change that has been and is taking place as a result of innovation in urban PV. Understanding the difference between novelty and normalcy as constantly and actively interdefined in processes of innovating, a series of urban sites of change are presented as relationally constituted shifts in the conditions of possibility. On the whole, the discussion of findings in Chapters 4-6 provides an analysis of innovation across a wealth of empirical material, providing an original analysis of innovation in urban PV.

4 Urbanising photovoltaics

4.1 Introduction

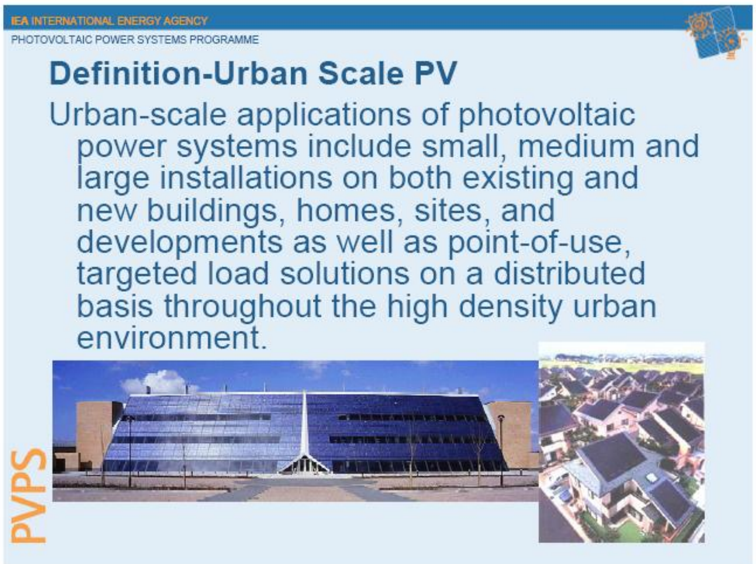

Figure 4.1 IEA PVPS Task 10: definition of urban PV
(Source: Herig 2007, powerpoint presentation, *Urban-Scale PV Applications,* Fukuoka, Japan; **#G7**)

The expert panel of the International Energy Agency's (*IEA*) *Photovoltaic Power Systems Programme* (*PVPS*) has come up with a straightforward answer to the question of 'what is 'urban' PV?': it is defined as any PV system which produces photovoltaic power in the "high density of the urban environment". However, it is the chapter's central contention that what makes an 'urban photovoltaics' transcends a functional definition based purely on the physical location of artefacts. Perhaps somewhat problematically, over the course of the research few people (besides the *IEA*) in fact employed the term 'urban photovoltaics' explicitly, or consistently. Reflexively speaking, the very term 'urban photovoltaics' can be seen, largely, as itself an artefact of this thesis' desire to formulate an account of this technology (see Chapter 3). From a material semiotic position, the *IEA*'s and my own use of the term should thus be positioned as two of potentially numerous and diverse realities which can be understood as contributing to constituting the 'itness' (van Loon 2002) of an 'urban' photovoltaics. As such, this chapter does not set out to discredit the *IEA PVPS* experts' understanding of urban PV. The principal aim of is to develop an account of urban PV that is sensitive to a multiplicity of potentially numerous non-coherent technological realities. The intention is to provide a layered understanding of what might be understood by an 'urban photovoltaics' in order to advance our understanding of the myriad of materials, spaces and actors that emerge as playing a part in urbanising PV in Barcelona, London and Paris.

To this end, the material semiotic analysis of urban PV is developed in three steps building on the analytical concepts developed in Chapter 2. In the first instance, Section 4.2 explores the diversity of aspirations that PV technology is designed to bring about – in what ways, in the sense of being purposeful is the context of human activity, is urban PV a technology? This is done through attending to how different actors enact PV materially and discursively in their activities as an 'utopical' entity. The utopical adjective is thus used to suggest that PV mediates the conversion of a diversity of actors' aspirations into practice. The section describes three parallel versions of PV which co-exist alongside one another within and across Barcelona, London and Paris. The basis of these different realities is explored in Section 4.3. Here the notion of 'utopical techniques', introduced in 2.5.3, is used to refer to the relational work that materially heterogeneous entities perform in terms of serving as nexuses around which actors attempt to spatialise desirable states of affairs. The section is particularly concerned with decentring the artefact as the sole or even most important materiality of technology by delving in more depth into urban PV's 'sociomaterial architecture', taken to refer to a set of common building blocks of utopical techniques. While Section 4.2 and 4.3 provide an analysis of the sorts of relations actors seek to gather and their sociomaterial means for doing so, Section 4.4 explores the diversity of ways in which actors innovate. It is argued that the intelligibility of an 'urban photovoltaics' emerges as actors apply a combination of different utopical techniques in their 'utopics' – utopian spatial practice. As such, the overarching argument this chapter presents is that urban PV is both an *outcome* of, as well as a *means* for, innovation: it exists in and through actors' innovative practices, which effectively serve to enact it as a vehicle for converting their aspirations for change into actual states of affairs (however successfully, see Chapter 5 and 6). The chapter moves from first evaluating the technological realities of urban photovoltaics largely irrespective of geographical context, to conclude with a reconstruction of the urban PV 'scenes' in Barcelona, London and Paris specifically. Such an material semiotic analysis provides a geographically and temporally sensitive account of the emergence of urban PV in the European cities chosen as empirical cases through an inquiry into aspirations, means and modes of innovation.

4.2 Utopian solar aspirations

1

2

3

Figure 4.2 Multiplicity of urban PV

(Sources: [1]Fundación Tierra 2009, *Guerrilla Solar: el kit fotónico GS120.* **#B69**; [2]Solarcentury website, *Picture library*. **#L188**; [3]IDEMU 2009, *"Le solaire à Paris : c'est possible!".*Presentation par Clément Tranain. **#P50)**

From a definition such as the *IEA PVPS*'s experts the three systems pictured above are unproblematically 'urban' technologies: the small terrace shading system (of approximately 120 watts), the residential building-integrated roof tile (between a 1 and several kilowatts) and the building-integrated roof of a large-scale urban regeneration project (of several hundreds of kilowatts). Each generates power (at least whilst the systems function) in Barcelona, London and Paris, respectively. From this perspective, residential terraces, rooftops and regeneration projects might be viewed as different 'applications' for the same technology. Such an understanding, of PV as brought to the city through different 'technological niches', would be an account of the diversity of these systems proposed by frameworks in innovation studies such as 'Strategic Niche Management' and the 'Multi-Level Perspective' (*SNM*/*MLP*). It is argued here that this constitutes a largely legitimate *description*, however that such an account fundamentally fails to account for the fact that these three systems are not just different urban PV artefacts that generate electricity in the city. The material semiotic account of technology (see 2.5.1) of this thesis proposes that the purpose of technologies such as urban PV should not be taken for granted, but interrogated. While it may be the case that each generates urban scale electricity, it should not be assumed that their status as technology *for particular actors* derives necessarily, or only, from the way they gather electrons from the sun and convert these into power. This section explores the terrace shading installation, the glazed roof of the urban regeneration project and the building-integrated roof tiles as paradigmatic of three distinct ways in which PV is 'utopical': as a technology for *eco-empowerment*, for *carbon reduction* and for securing *livelihoods*, respectively. Rather than assuming that technologies are the same everywhere and at all times (Orlikowski 2010), this section draws on material semiotic sensibilities to develop an analytical sensitivity for understanding the diversity of roles that technologies play for different actors, in their particular contexts.

4.2.1 Eco-Empowerment

Layers of meaning are added to the schematic depiction of the terrace shading system in Figure 4.2-1 when it is considered in its wider web of relations. The 'photonic kit GS120', in some places found affixed as a shading device on sunny Barcelonan terraces, is the material nexus of the 'Solar Guerrilla' campaign of Barcelona-based non-profit *Fundación Tierra.* Crucially, the campaign is designed to raise awareness about the difficulties facing small-scale power generators in connecting to the electricity grid in Spain (see further Section 5.2), thus critiquing the existing legislative set up through. The GS120 is part of a broader portfolio of campaigns and projects about renewable energy and energy sustainability (see Section 4.4.2), which are explicitly framed as issues of 'energy democracy'. The role of PV in general in the organisation's activism was described by its President and founder as well-suited to enacting the organisation's broad philosophy ("We decided that solar energy is an avenue through which everyone can give back the energy they consume"). In this context, the guerrilla PV kit constitutes a very real and material nexus around which *Fundación Tierra* gathers gather not only the roofs and terraces of a range of prospective 'solar guerrilla warriors' (*guerrilleros*), but also private sector actors, charged with the manufacturing of the panel, on the one hand, and public and regulatory agencies who have become aware of the campaign (Fundación Tierra 2009). The underlying conviction, embedded in the *Fundación*'s charter, is that when energy from the sun is harnessed on private individual's rooftops this can bring about more environmentally as well as socially equitable relationship between society and nature.

The photonic kit GS120 of the Solar Guerrilla… is a solar appliance that functions as easy and safely as a fridge, but instead of consuming energy… generates small energy savings, as it stops electricity being drawn from the main electrical supply while it feeds in power from the sun through a common domestic plug. At times when no one is consuming, the kit's watts per hour are released into the general electrical supply, as a sort of 'green energy' donation.[1]

***

It's an 800 Euro panel of 130 watts. It's nothing. Really, we are talking about a bare minimum of electricity, perhaps enough for a household fridge. Above anything else, it's to visualise the problem, because there *is* [emphasises] something wrong and we think something needs to be done about it.[2]

Figure 4.3 Kit Fotónico GS120: power to the people.

(Source: [1]Fundación Tierra 2009, *Guerrilla Solar: activismo ecológico sin tapujos* (**#B88**); [2]President, *Fundación Tierra*, Interview, Barcelona, March 2009)

PV as a technology for a sort of 'eco-empowerment' is present beyond the confines of the *Fundación*'s offices. In this way of being purposeful, that is 'utopical', PV is understood as an environmentally-friendly technology as well as a 'democratic' electricity generator that promises to source electricity in a ‘socially equitable’ manner. This however, depends upon the ownership of PV systems being in the hands of households and communities (as opposed to ‘traditional generators’, such as energy companies). The notion of community eco-empowerment, blending of PV’s ecological and social purpose is also present in the following extract from the UK-based *Green Alliance*, an ‘environmental think tank’ (http://www.green-alliance.org.uk/aboutus/), which understands PV under the broader banner of ‘microgeneration’[19]:

> Micro-generation will make the public co-producers of climate change solutions rather than passive consumers of energy… Micro-generation means building climate change solutions into everyday life, and giving individuals and communities contact with, and control over, the generation of green energy.
> (Green Alliance 2004: 6, *A microgeneration manifesto*. **#L55**)

Generating solar electricity is associated with an ethical form of resource consumption that is respectful to natural and human environments in the present and projected as an intergenerational issue into the future. As in *Fundación Tierra*’s case, the Paris-based non-profit *Comité de Liaison Energies Renouvelables* (*CLER*) also understands PV as a technology that has potential for redressing the democratic deficit in existing energy systems. A publication by *CLER* entitled ‘Subjects or Citizens? Elements for a grey paper on energy in France’ (Jedlizcka and Lenoir 2007) is kindred to the Barcelonan Solar Guerrilla movement in terms of its explicitly subversive character. This is suggested, for instance, by the mocking notion of ‘grey paper’ in its title, which mimics governmental public policy ‘white’ and ‘green’ papers. As the following extracts from the essay more explicitly indicate, decentralised PV systems are seen as enabling a move away from centralised power generation where the ownership of infrastructure and the rewards of power generation is concentrated in the hands of a few, monopolistic corporations:

> Our country needs to adopt a more ambitious "sustainable" energy policy, that is to say, based on prioritising simplicity, efficiency and renewable energy… not under the control of central government, national public services and large enterprises. Indeed, such a politics cannot be imposed in a ‘top-down’ fashion…

[19] In the report microgeneration refers to the generation of ‘clean’ (in this case zero- or low carbon) power and heat near the point of use. In the UK there is a statutory limit of 50kW to microgeneration.

> … photovoltaics, in addition to its immense economic and environmental benefits, will be able to make a vital contribution to the "energy responsibility" of individuals, organizations, territories and the whole society, which is a prerequisite for the sustainability of the human species on Earth.
> *(*Jedlizcka and Lenoir 2007: 5; 38, *Sujets ou citoyens ? Éléments pour un livre gris de l'énergie en France*. **#P55**)

The 'grey paper' articulates the aspiration of a transition from energy 'consumers-as-clients', a consumption relationship between a client and a service provider, to a new form of 'energy citizen' subjectivity that is defined in terms of humans' ecological relationship, as a species, with the planet as a whole. For actors such as the *Green Alliance*, *Fundación Tierra* and *CLER* PV thus constitutes a technology for linking a more 'sustainable', ecologically benign form of anthropogenic resource consumption to the natural environment. This is provided that the technology is used in such a way as to open up the possibility for non-traditional generators – individuals, households and communities – to engage in ecologically friendly power generation.

Similarly sensitive to PV's potentially environmentally beneficial effects, the following section explores a second way in which PV is utopical*.* Here the large urban regeneration project in Paris is taken as paradigmatic for a PV's status as a technology for *carbon reduction*, which is ecologically orientated, however far less critical of the socio-economic relations in existing electricity systems.

4.2.2 Carbon reduction


ENVIRONNEMENT

Agir localement, pour la planète

Face à la menace planétaire que représente le réchauffement climatique, il faut agir. C'est pourquoi depuis 2001, toute l'action municipale a été fondée sur l'impératif du développement durable, qu'il s'agisse des déplacements, des crèches et des logements sociaux réalisés en haute qualité environnementale (HQE), ou de la consommation d'électricité dont la part destinée à l'éclairage public a diminué de 80 %. Déjà, **de véritables écoquartiers naissent à Paris**, comme aux Batignolles, à Rungis, Boucicault ou Claude-Bernard.

Le **Plan Climat** que le Conseil de Paris a adopté en octobre 2007 fixe des objectifs particulièrement ambitieux : ainsi, pour la prochaine mandature, nous proposons de **réduire de 15 % l'ensemble des émissions de gaz à effet de serre (CO_2) produites à Paris**.

Pour tous les programmes d'aménagement nouveaux, nous tendrons vers l'objectif d'un bilan énergétique neutre **(zéro émission de gaz à effet de serre)**, voire positif. Un grand **plan de réhabilitation des 171000 logements sociaux**, sera engagé, visant l'objectif d'une réduction de 30 % des consommations énergétiques en 2020.

Paris, capitale mondiale de l'énergie solaire! La Ville engagera (comme ici à la Halle Pajol, 18e) un vaste plan d'installation de 200 000 m² de panneaux solaires d'ici 2014.

In face of the planetary threat of global warming, action is required… the *Plan Climat* that the Council of Paris has adopted in October 2007 sets particularly ambitious targets: for the coming term, we propose to reduce by 15% greenhouse gas emissions (CO2) emitted in Paris.

Paris, world capital of solar energy! The city is committed (as shown here with the ZAC Pajol, 18e) a vast plan of installation 200,000 m2 of solar panels by 2014.

Figure 4.4 "Act locally, for the planet"

(Source: Delanoë 2008, *PARIS, UN TEMPS D'AVANCE.* **#P30**)

In an appropriation of the environmental movements' slogan ("think global, act local"), the *Mairie de Paris* has set itself 'ambitious' greenhouse gas emission reduction targets (see Figure 4.4). Announced in 2004, the ZAC Pajol in the 18th *arrondissement*, is one of Paris' largest regeneration projects. The project aims to turn a derelict railway station into an 'eco-neighbourhood' which will house, amongst other leisure facilities, a youth hostel, whose roof is to be covered with 3,500 m^2 of PV panels. Here PV forms part of broader initiative through which the local Mayor of the 18th *arrondissement* and the public-private developer *SEMAEST*[20] are drawn into the *Mairie de Paris'*

[20] *Société d'Economie Mixte d'Aménagement de l'Est de Paris.*

and in particular Parisian Mayor Delanoë's broader urban climate protection policy. In the *Mairies*' 2006 climate change strategy (*Plan Climat*) and Mayor Delanoë's 2008 re-election manifesto PV features as one of numerous means through which ambitious GHG and carbon reduction targets for the city – municipality proper and the urban territory more generally – are to be achieved over the coming years. The implications of the Mayor's use of PV specifically as a technique for urban transformation are explored in depth in Section 6.3. For the present it should be noted that the urban authority is not alone in foreseeing a role for PV to play in climate and renewable energy policy. As illustrated by the following extract from a report to the French national assembly:

> The development of PV in France is situated in this framework of the objectives set in the *Grenelle de l'environnement*[21]… [it] foresees to increase the share of renewable energies by at least 23 % in the country's final energy consumption by 2020. This target corresponds to the objective set out in the European "climate-energy" package… Public support is justified with respect to the environmental qualities of this [photovoltaic] mode of electricity production…
> *(*Poniatowski 2011: 7-8, *Quel avenir pour la filière photovoltaïque française?.* **#P96**)

As the quotation suggests, it is in the context of environmental governance processes at various levels of government (and including non-state actors) that PV is a technology that acquires significance in terms of its 'environmental qualities'. That climate change has found its way on political agendas worldwide is a well-documented reality (Bulkeley 2011; Hodson and Marvin 2010; Betsill and Bulkeley 2008). The national governments of France, Spain and the UK have each developed climate change and energy strategies or plans which translate the dual multi-lateral UN and intergovernmental EU commitments into national emission reduction targets[22]. At the regional level, the European Union issued the '20-20-20' climate and energy package (EU 2009) which constitutes a threefold commitment to emission reductions, renewable energy and energy saving (of 20 percent below 1990 levels). Internationally, the Intergovernmental Panel on Climate Change's fourth assessment report (IPCC 2007), the United Nations Framework Convention on

[21] National French climate change negotiations, a roundtable consultation format.
[22] For instance, the *Grenelle de l'environnemnt*, a multi-party cross-sectoral debate on environmental policy, outlines the French 'factor 4' approach of reducing by 75 percent greenhouse gas emissions by 2050; the Spanish Climate Change and Clean Energy Strategy (*EECCEL*) is part of the Spanish Sustainable Development Strategy (*EEDS*). The *EECCEL* includes different measures that contribute to sustainable development within the scope of climate change and clean energy.

Climate Change (UN 1992b) and the Kyoto Protocol (UN 1998) are seen as the background for regional, national and local commitments to reducing greenhouse gas emissions.

In the context of these ‘climate protection’ efforts, the urban authorities of Barcelona, London and Paris have each formulated comparable commitments to emission reductions, which centre (as at the national government policy scale) on three main ‘pillars’; of increasing the share of renewable energy (in national and urban portfolios), energy efficiency and energy saving (Mairie de Paris 2006a; Ajuntament de Barcelona 2003b; GLA 2004). In this context, PV is a technology for achieving the aim of emission reductions ‘directly’ through its potential to contribute a renewable – and hence ‘low carbon’ – form of electricity supply. Here PV’s precise contribution is frequently seen as relatively limited (see 4.3.2) – however, as will be seen, there’s no consensus on precise figures (see Section 6.4). On the other hand, by ‘indirectly’ constituting a means through which it is thought that the wider population becomes involved in climate protection, PV is a technology for a more subtle form socio-cultural transformation; for instance, in terms of changing prevalent consumption practices and attitudes to new energy infrastructures. As the following extract from the ‘UK Renewable Energy Strategy’ illustrates, it is thought that

> Rolling out renewables as a part of everyday life – for instance… solar panels on the neighbour’s roof – can increase public acceptance of renewable energy projects such as wind farms, and encourage everyone to reduce their energy demand.
> (DECC 2009: 62, *The UK Renewable Energy Strategy*. **#L21**)

Even the regional Catalan Energy Plan, generally acknowledged to be conservative in its ambitions for the technology, acknowledges the behavioural importance of PV for engaging the public at large with energy-related issues:

> The social acceptance of this [PV] technology on behalf of society at large and the fact that it is a tool for raising awareness about the rational use of energy and renewable energies in general means that it is of continuing relevance and its implementation should be promoted.
> (Generalitat de Catalunya 2006: 219, *Pla de l’energia de Catalunya 2006-2015*. **#B91**)

In terms of being a technology for direct carbon reductions it “doesn’t matter what you do” (Academic Professor, *Northumbria University*, Interview, Newcastle, December 2008) – the technology ‘mitigates’ carbon emissions wherever the technology is placed and whichever artefact form it takes (i.e. standalones, rooftop panels or building-integrated). Its ‘indirect’ work of raising awareness is generally more significantly tied to being positioned in public and community sites in which it is visible; such as the installation at the ZAC Pajol in Paris. In instances where the PV system itself is not visible (for instance, it is high on an urban rooftop) there may be display monitors that are positioned in a way that is more visible to the public eye (see Section 4.3.1 below). For instance, in the case of the rooftop installation at Spitalfields’ Bishop Square in East London

> A solar 'totem' display stands outside the main entrance of the new development to communicate benefits of solar energy to the buildings occupants and passers by… The reverse of the totem provides information for the community highlighting the importance of clean energy and how PV generates electricity from daylight.
> (Solarcentury 2007, *Spitalfields Bishops Square*. **#L182**)

Contrary to PV as a technique for eco-empowerment, as a technique for carbon reduction it is not the ownership of PV that is at stake, but its geographical positioning; either within a particular territory, as a tangible contribution of meeting climate protection targets, or in places through which many pass, and which may for instance, as London’s City Hall, due to their “iconic design and landmark location… be seen by over 3 million people a year” (Allan Jones cited in *London's City Hall goes solar,* Mayor of London 2006. **#L136**)

In important ways, understanding PV as a technology for carbon reduction and eco-empowerment thus provides a more nuanced perspective of the purpose of this technology, relating to the ownership of power generation infrastructure as well as the ecological mediation of power generation and consumption practices. The following section considers a third way in which PV is utopical that frequently plays on themes of empowerment and environmentalism, however ii is fundamentally concerned with something rather different: as a technology for securing a livelihood, PV enmeshes market exchange relationships in the activities of another set of actors across Barcelona, London and Paris.

4.2.3 Livelihoods

> [Solarcentury] generates a sale, it delivers a product and a service, and it gets paid for it. There's relatively little that's magic about that… I think the projects will always be there but you want the real growth to come from these products which people will buy… you want to sell a product where you're pushing an element of the work down the chain… that's the way you will grow as a products company. So we have one product, we have variations on that particular product and there are new products in the offing…
> (Project manager, *Solarcentury*, Interview, London, November 2008)

Figure 4.5: Product business

(Source: [1]Activatesolar.co.uk. **#L1**)

Solarcentury's 47W solar roof tile is a building-integrated PV product which can be relatively easily 'clipped' onto new or existing rooftops as a substitute for non-electric building tiles. It is a clever product in the sense that the tiles are easy to install, they mostly circumvent (at times problematic) issues of planning permission, whilst (once installed) "protecting your property from the elements and producing power for your home" (Solarcentury 2007. **#L179**). In the case of *Solarcentury*, the tile is the latest in a series of evolutions in the business' portfolio of activities, which have included moving from an early focus on relatively small-scale projects, to commercial scale installations, government contracts and, through the tile, the move from being a purely 'project' business to a 'product' business (Project manager, *Solarcentury*, Interview, London, November 2008). The difference between the two is that the latter is more lucrative, as solar installers further along the supply chain nationwide begin using *Solarcentury* roof tiles. This is a strategic move of “pushing an element of work down the chain” (ibid.) through which profit can be made and the company expanded and the company retains an overview of the expanding market. This is not to say that *Solarcentury* is not a “business with a purpose” (see 4.4.3), as it proclaims on its website – however, this should not detract from the fact that the environmental credentials of solar panels may at times not be more than a selling point. This form of marketing is suggested, for instance, by *Hyundai Solar*’s use of the anthropomorphised polar bear figure beckoning onlookers to purchase ‘a single Solar Module’ (See Figure 4.6). However, in contrast to eco-empowerment and carbon reduction, here PV’s ‘green-ness’ is not necessarily (or even at all) an important aspect of how PV works as a technique for a set of commercially-orientated actors, who are seeking to make a livelihood. For instance, in the second advertisement reproduced from the industry magazine *Sun& Wind Energy* (S&WE 2008), *SCHOTT Solar* plays on the technology’s “robust” and “long-lasting” characteristics (for “Whatever the future holds”) while *Techno Sun* uses a ‘photovoltaic football’ to generate appeal for PV based on its “competitive service” and “highest performance” (see Figure 4.6).

There’s little doubt that PV is a technology that sustains livelihoods worldwide. In 2010 the global PV industry was a € 40 billion “fully-fledged mass-producing industry”, growing at over 50 percent a year, with a job creation rate of between 7 and 11 jobs for every megawatt of PV installed (UNEP 2008 cited in UK-PV 2009) – and about 24 to 26 GW are currently in the process of being installed in Europe (JRC 2010: 108). The ‘upstream’ area of the value chain is fairly concentrated, with few suppliers of silicon, cells and module manufacturers making up the global market. Production and manufacturing is a geographically diffuse activity, with major production centres in Asia, Europe and the US (ADEME 2007, **#P8**). In contrast, the ‘downstream’ is much more diffuse and fragmented, including a myriad of academic and commercial R&D institutes, wholesale module retailers, installers and other building professionals (some but not all specialising in PV specifically) (PWC 2010). Umbrella organisations such as the solar industry lobby associations *ASIF*[23] (Spain), *SOLER* (France), *REA/STA*[24] (UK) and *EPIA* (European-wide) each boast several hundreds of members. The Spanish PV industry association, *ASIF*, estimates that the Spanish PV industry could

[23] *Asociación de Industria Fotovoltaica.*
[24] *Renewable Energy Association*; the *Solar Trade Association* (*STA*) re-launched in 2011 as affiliated to REA to represent solar industry interests in the UK.

employ up to 56,000 persons by 2020 in manufacturing, installation and maintenance and 10,000 by the UK's *Renewable Energy Association* (REA 2011) (to rise up to 17,000 by the end of 2011).

Figure 4.6 Solar ads: environmentalism, durability and performance
(Source: S&WE: 2008. *Sun &Wind Energy: International Issue 04/2008*. **#G14**)

For a particular set of commercial actors PV is a technology that works through gathering a range of economic relations between (for-profit) company and clients, upstream suppliers and manufacturers, governments – amongst others. For instance, while prospective consumers are engaged into economic market relationships, for governments a thriving domestic solar industry is positioned as a potentially vital part of domestic economic development and industrial policy. In this way, the Spanish renewable energy strategy[25] (Gobierno de España 1999: 16) states that the national PV sector "constitutes an important reservoir of employment and an opportunity for business creation and the development of new industrial sectors". Similarly, a 2010 report to the UK *Department of Business and Innovation* situated PV within the top ten of 'high growth sub sectors' of a broader set of low carbon and environmental goods and services (LECGS), estimating the sector's value at £4,721 million in 2008/9 (and projecting it's value at £6,936 million in 2015) (Innovas Solutions Ltd 2010). Stressing the particular relevance of growth and employment in the PV sector, a report to the French National Assembly states that, "like any other industrial and commercial sector, the photovoltaic sector creates a large amount of jobs that cannot be ignored in this time of economic crisis" (Poignant 2009: 36; original emphasis). The economic importance of PV for policymakers extends to urban authorities such as the (then-) Mayor of London Ken Livingstone, proposing that PV industry in London itself could take the form of 'local manufacture' in terms of module assembly and the production of photovoltaic building materials, for export as well as direct use in the city (GLA 2004: 145).

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In sum, this section argues that an analysis of urban technology must be attuned to the diversity of ways in which a technology such as PV becomes purposeful in a variety of ways, for different actors. A relational understanding of technology eschews a purely geographical and artefactual account – of an object generating electricity in the city – in favour of evaluating the variety of purposes that a seemingly singular technology may constitute for different actors and in different contexts. Crucially, such an account of PV technology understands the three systems introduced in this section – the phototonic kit GS120, the solar tile and the building-integrated system of the ZAC Pajol – as entangling very different sets of relations in order to be considered 'working' technologies for *Fundación Tierra*, *Solarcentury*, and *Mairie de Paris*, respectively. As Table 4-1 summarises, in each case PV technology is aspired to bring about rather different outcomes. While

[25] *Plan de Fomento de las Energies Renovables.*

Fundación Tierra's eco-empowerment aspires for more ecologically and socially just relations with its photonic GS120 panel, the *Mairie de Paris*'s regeneration project forms part of its ambitious urban scale carbon emissions reduction strategy and *Solarcentury's* C21e solar tile is yet another business savvy strategy for growing and expanding the business.

Importantly, in each case aspirations for eco-empowerment, carbon reduction and livelihoods are inextricably tied up with, however transcend, (the *IEA*'s) technical definition of urban PV as a technology for city-scale electricity generation. Substantive differences between technologies for eco-empowerment, carbon reduction and livelihoods bring into focus a question concerning the basis from which differences materialize. In other words, how is it possible, analytically, to account for the emergence of such different technologies that do not just look different but, crucially, are put to work in different ways by different actors? This is the theme of the following section. It is argued that what underlies the functioning of different urban PVs is a common 'sociomaterial architecture'. This is taken to refer to the existence of a set of building blocks that when put together perform the intelligibility and coherence of particular urban PV technologies for eco-empowerment, carbon reduction and livelihoods.

Table 4-1 Utopian solar aspirations

Desirable outcomes	Relations to be gathered	Actors	PV Examples
Eco-empowerment	Civil society into more ecological and socially just relations	Third sector	*Fundación Tierra*'s Photonic kit GS120
Carbon reduction	Low carbon electricity generation for achieving policy targets	Public policy	*Mairie de Paris*'s ZAC Pajol
Livelihoods	Costumers and policy support for profit and business expansion	Commercial	*Solarcentury*'s C21e solar tile

4.3 A common sociomaterial architecture

The concern of the present section is with the material substance of 'urban PV' technology (Lovell 2005). The fact that few actors themselves in fact use the terminology of 'urban PV' requires me to justify this analytical move in terms of its centrality to the thesis as a whole, which is concerned with understanding processes that shape innovation in 'urban PV'. Critically, searching for the coherence of an ‘urban’ PV draws into focus the performative effect of my research methodology and methods (see Chapter 3), which itself enable an object such as ‘urban photovoltaics’ to come into being in the present form. Wary of this performative effect, the proposition is that there is a common relational ‘architecture’, which is the means by and through which it could be argued that an ‘urban PV’ is emerging, by being relationally enacted. The term architecture is here used not to indicate rigid structuring principles but to suggest that there are a set of elements that are *shared* by different technologies for eco-empowerment, carbon reduction and livelihoods. Here Chapter 2’s notion of ‘utopical technique’ is central. ‘Techniques’ are understood as ‘things’ that *gather*, in the sense of bringing entities together into heterogeneous associations (Heidegger 1977; Latour 1999b; Postma 2009). The term captures the relational role that different entities have in constituting and mediating relations and often constitute what Latour (1992) termed the ‘missing masses’ that are frequently sidelined in analytical processes. The utopical adjective suggests a focus on those entities which are used as techniques for bringing about desirable states of affairs.

It is the contention of this section that there are *common patterns of relations*, a common architecture, that are the building blocks from which technologies of eco-empowerment, carbon reduction and livelihoods are made. This section proposes that an ‘urban PV’ is enacted in sociomaterially multiple ways across different utopical techniques; each which themselves gather sets of relations in distinct ways (see 2.5.1). As such, utopical techniques can be understood as underlying the coherence of functioning of technologies. Rather than viewing technology as artefacts which ‘grow’ and ‘stabilise’ in discrete sites (i.e. ‘niches’; e.g. Schot (1998a)), several utopical techniques are distinguished from one another in order to move beyond equating technologies with the ‘artefact’. The suggestion is not that the here explored *artefacts, texts, events* and *finance* are necessarily the only elements constitutive of urban PVs architecture, but that these are important features, and that it is important to account for this multiplicity. Through discussing of each of these in turn the section seeks to tease out aspects of the relational work that these different elements perform as utopical techniques that gather a range of simultaneously social, material, spatial and temporal relations. The merit of accounting for the heterogeneous make up of this architecture ‘beyond the artefact’ is that it makes it possible to account for the various ‘substances’ (Lovell 2005), the very means through which innovation takes place.

4.3.1 Artefacts

While not the only utopical technique, artefacts are important aspects of urban PVs architecture. To appreciate their role as mediators of relations the material semiotic notion that artefacts are not simply objects that exist *in* space but are *themselves enacting* particular sociomaterial spatial relationships (Law 2002a; Koch 2005) is particularly useful. The argument that "making objects indeed has spatial implications" (Law 2000a: 2) for drawing attention to the particular forms of socio material and spatial realities of urban PV that artefact may perform. For instance, the map of Barcelona reproduced in Figure 4.7 displays a number of existing and prospective municipal PV installations across the geographical administrative city; showing at least one project per city district. The Municipal Photovoltaic Programme performs a particular distribution of PV systems across the city (see Figure 4.7), involving the installation of PV systems on libraries, schools, and community centres where each of the 10 urban districts is 'recipient' of at least one PV project. Municipal PV projects have also taken place in London as part of the *Greater London Authority*'s (*GLA*) broader climate protection policy. However, contrary to the *Ajuntament de Barcelona*'s spatially homogeneous distribution of systems on public and community buildings, the *GLA* 'flagship' installations are much more territorially distributed across Greater London, including administrative buildings such as City Hall and Palestra and fire stations across the city's boroughs. This is related to a range of reasons, such as different extents of building stock ownership of the two urban authorities (despite a shared use of PV as an utopical technique for carbon reduction) (Ajuntament de Barcelona 2003b; GLA 2007).

The inscription of intention into artefacts (Akrich 1992; Pfaffenberger 1992), whatever this is in practice, performs a series of 'solarised' urban spaces which serve to enact quite distinct realities of urban PV. They may, for instance, relate to 'learning', as in the case of Barcelona's *Ajuntament*'s ambition to develop a more diverse use of types of building-integrated PVs ("pergolas, facades, terrace shading, building-integration and substitution of construction elements" (Engineer 1, *Interview*, Barcelona Energy Agency); or alternatively, to "educate about environmental values" (Agència d'Energia de Barcelona/Ajuntament de Barcelona: 2007; **#B8**). Alternatively, then-Mayor Livingstone used the *GLA*'s flagship installations to 'lead by example'; and the *Ajuntament* also uses its PV initiatives to promote Barcelona as the city "making most use of solar energy" (Ajuntament de Barcelona 2003b). In contrast , the early 'pioneering' PV installations of *CLER* and *Fundación Tierra*, seeking grid connection in a highly centralised electricity system (see Section

5.3.1) exposed the 'veritable obstacle course' (Jedlizcka and Lenoir 2007) that may face those aspiring to install small-scale grid-connected but non-centralized electricity generating technologies. Other one-off projects include the small domestic system of a regular citizen, 'David Elridge', publicized by the UK Energy Saving Trust's as an exemplary 'case study' of PV for domestic households to incite others; and the participatory 'Solar Wave' (*Ola Solar*) on a municipal market in Barcelona (see Sections 4.4.2 and 6.5), which is positioned by its instigators as an "initiative of popular capitalism" (*Fundación Tierra* 2007. **#B74**).

Figure 4.7 Barcelona municipal PV installations
(Source: *Instal·lació de Centrals Fotovoltaiques en equipaments municipals de la Ciutat de Barcelona*, Agència d'Energia de Barcelona/Ajuntament de Barcelona: 2007. **#B8**)

While generally falling under one of the three solar aspirations explored in the previous section, the precise gathering function of these artefacts is not inherent to the act of implementing these projects. Importantly, the sociomateriality of these artefact-based initiatives transcends the boundaries of the artefact itself. As the case of the 'solar totem' in Spitalfields' Bishop Square illustrates, intention is delegated not only to the rooftop system, which is invisible to the passersby on the street. Rather,

> The core idea of the display is simple… to deliver a street-level experience communicating the benefits of the thirteenth-floor solar installation to an audience of people working in Bishops Square, shoppers and passers-by.
> (More Associates 2008, *Bishops Square*. **#L154**)

Artefacts such as the solar totem, Barcelona's municipal PV installations – and many others – make it possible for some actors to become spokespersons for a range of relations (whether through the system itself or its street level extension). For instance, artefacts such as the *Ola Solar* and the photonic kit GS120 enable *Fundación Tierra* to speak on behalf of the 'solar stockholders' of the Solar Wave and a range of 'solar guerrilleros'; just like *Foster+Partners* and the other parties implicated in the implementation of the solar totem are creating the reality of an urban PV that is for 'the people' of the area – the "4,000 people" who work in the building and the "many more who will pass the site while commuting, shopping and so forth" (ibid.; Figure 4.8).

Figure 4.8 Artefact and public space
(Source: More Associates 2008, *Bishops Square*. **#L154**)

Importantly, none of these artefact-based initiatives in fact ends ‘at the panel’. Each of these is tied up with a broader range of materialities – websites, promotional literatures, press releases – and many more. This aspect of artefact-based initiatives alerts of another aspect of urban PVs sociomaterial architecture takes, namely that of ‘texts’.

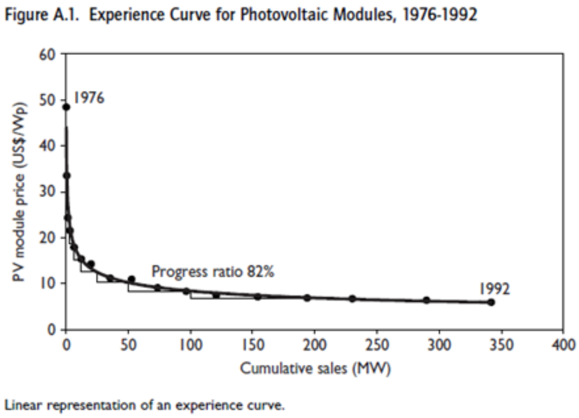
4.3.2 Texts

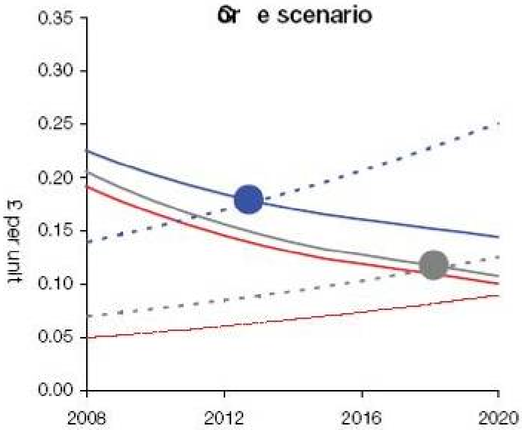
A diversity of ‘literary inscriptions’ (Callon 1991) of various forms were found to be the single most ubiquitous utopical technique of urban PVs architecture – forming, for instance, the bulk of data collected and analysed (see Chapter 3). Most basically, texts consist of “words, ideas, concepts, and… a whole population of human and non-human entities” (Callon 1991: 135), they are authored by and for humans, and continue to bear the intention of their creators as they ‘travel’ away from their original site of creation (Latour 1990). While texts raise important questions regarding authorship, intended audience and manner of circulation, the sheer number and diversity of textual sources – ranging from short press releases and one-page factsheets to comprehensive technical reports and governmental strategies (see Appendix A) – defy a parsimonious way of categorising these in the limited space presently available. There are, however, key aspects of textual sociomateriality that merits exploration in terms of the ways in which they enact particular realities of urban PV. Beyond the written word, Law and Whitaker (1988) distinguish (non-exhaustively and non-exclusively) between different techniques of representation which are frequently used in texts. They propose that visualization and text may come to stand in a “reflexive, mutually warranting relationship” (Law and Whitaker 1988: 181) with one another in several ways: the referencing of other publications, quantification, photographic realism and semi-naturalistic depiction; each of which derives their legitimacy and basis of appeal, respectively, from appealing to expert authority, the presentation of ‘objective’ facts, visual snapshots of reality and the blending of particular storylines with conventionally recognisable elements.

For instance, in a range of strategic public policy documents, technical reports and advocacy groups’ publications, the authority of individuals, organisations and institutions is invoked for justifying interventions and particular positions on policy direction. Appeals to scientific, political and other expert authorities are present in *Greenpeace España*'s '100% Renewables'[26] (Greenpeace España 2007: 5) report, which states that the "United Nations group of experts on climate change (IPCC) confirms that human beings are causing a rapid global warming without precedent". Similarly the *Ajuntament de Barcelona* situates its "commitments to action at the local level" as backed up by "international commitments that Barcelona is a signatory of", such as the Heidelberg Declaration, the Aalborg Charter and membership of transversal climate protection partnerships such as *Klimabündnis* and *Energie-cités* (Ajuntament de Barcelona and AEB 2007: 8). The *Mayor of London*'s 'Climate Change Action Plan' cites the *Stern review* for arguing that "the costs of doing nothing and then trying to clean up the mess later will be much higher" (GLA 2007: iii).

Secondly, techniques of quantification are frequently blended into text-based arguments. In several publications[27] the contribution of PV to reducing carbon emissions and altering the composition of territorial energy mixes is modelled according to differently likely 'scenarios' that gather elements as diverse as electricity prices, temperature, climate, consumption patterns, population growth, technological progress into causal relationships. In this way, a set of objects become simplified and interrelated in the 'comfortable' and 'docile' space of the text (Law and Whitaker 1988: 163). Perhaps the most important quantification of PV is the numerical estimation of the point in time at which PV reaches 'grid parity'[28], i.e. is cost competitive with conventional electricity. This is captured through the juxtaposition of the (negative gradient of the) PV 'experience curve' and the (upwards sloping) curve representing expected rises in electricity prices (see Figure 4.9[2]). From this the UK-PV Manufacturer's association, a UK-based PV lobby group[29], argues that solar power will reach grid parity "much sooner than most forecasts suggest" (UK-PV 2009: 7); and the IEA/OECD that experience curves "demonstrate the rewards of long-range, sustainable efforts to make the technology competitive in the marketplace" (OECD/IEA 2000: 110).

[26] *Renovables 100% Un sistema eléctrico renovable para la España peninsular y su viabilidad económica. Resumen de conclusiones*
[27] Such as Barcelona's 'Energy Improvement Plan' (Greenpeace España 2005; 2007), Greenpeace Spain's 'Renewables 2050'[27] and 'Renewables 100%' reports (SEA/RENUE 2006), 'London Carbon Scenarios' (Smith et al. 2010)
[28] It should be noted that 'grid parity' is not an uncontested notion. There are multiple understandings of grid parity; such as a generation cost equal to domestic retail prices, commercial retail rates, wholesale market prices and the costs of wholesale generation. Regardless which understanding of grid parity is used it is notoriously difficult to estimate.
[29] Now part of the *Solar Trade Association* (STA)





1 2

Figure 4.9: Experience Curves

(Source: [1]UK-PV 2009; [2]Law and Whitaker 1988, *2020 A Vision for UK PV: An up to date and accurate analysis on the investment case for solar photovoltaics (PV) in the UK*. **#L203**)

In contrast to this 'evidence-based' form of argumentation, photographic realism and semi-naturalistic depictions frequently works alongside – in harmony or contrast – with the text that surrounds it (Law and Whitaker 1988). In promotional literatures the use of photographic realism is extensive, often used in conjunction with numerical and rhetorical argumentation, to construct 'case studies' and 'best practices' as successful projects that are desirable for replication. The distinct purposes that photographic realism and semi-naturalistic depiction serve is illustrated by the *London Climate Change Agency*'s (LCCA) case study brochure of the demonstration project at the GLA-rented 'Palestra' building (see Figure 4.10). The document makes use of all of Law and Whitaker's techniques of representation: by juxtaposing the authority of Allan Jones (former LCCA CEO), quantifications of PV's energetic and carbon reduction performance, and photographic and semi-naturalistic representations (the former, perspectival shot juxtaposes PV panels against London's skyline, including London icons such as Tower Bridge, Big Ben and St Paul's Cathedral, while the latter is used as a schematic that explains the technical functioning of PV technology).

In constituting a sociomaterial form that enables one to abstract particular messages in a simplified manner about the "messiness of the social world" (Murray Li 2007: 265; Rose 1999), texts are important features of urban PVs sociomaterial architecture. Besides rhetoric, they are thus also important communicative media that alert a diverse 'target audience' of the importance and relevance of urban PV. For instance, Figure 4.11 reproduces several flyers that have been used to advertise events that took place about PV specifically, or urban sustainability and renewable energy more generally. This draws attention to another type of architectural form that enacts PVs sociomateriality: events.

Figure 4.10: Blending styles of representation (photographic, semi-naturalistic, authoritative)
(Source: LCCA 2008, *Case Study 2: Palestra Building Integrated Photovoltaic System*. #L106)

4.3.3 Events

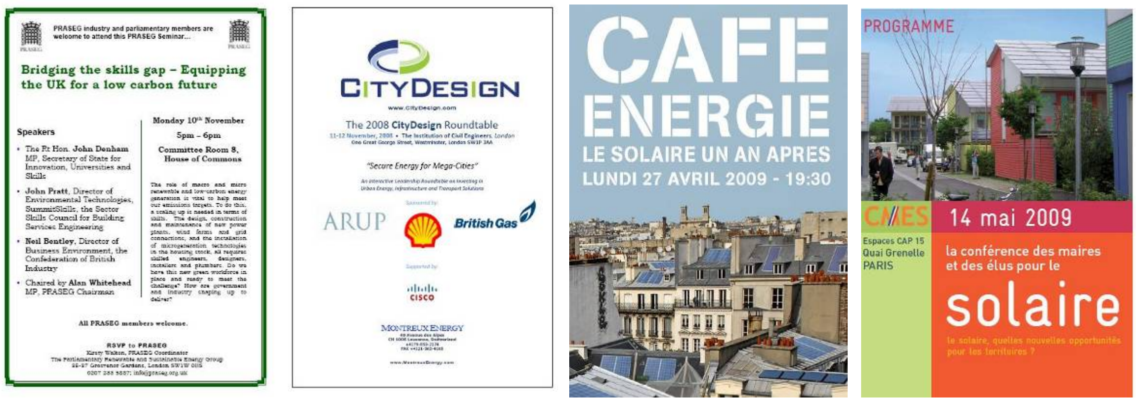


Figure 4.11 Event flyers
(Source: personal communications)

Events take place in particular locations and last a limited amount of time for the duration of which they enable direct interchanges between different actors. An important feature of events is that they are organised by particular actors, for specific purposes, involve a (sometimes, but not always) purposeful selection of participants. Hajer (2005: 626; 642), following Jasanoff (1990) and Wynne (1982), argues that the setting[30] of the event (location, material arrangements, lighting etc) itself strongly influences not only 'what is and can be said' but that different settings have a 'performative dimension': "practices of participation construct their participants… the public becomes what the setting makes it". Importantly, the series of events taking place over the course of data collection had very different settings; and as such are performative of urban PV in rather different ways. It is proposed here that events were of three main types differing in terms of the participants they brought together: celebrations (uniting those sharing a favourable disposition to PV), forums for debate (confronting those coming from different – and often not aligned – positions on PV) and informative events (aimed at disseminate knowledge about PV to potentially interested parties).

[30] In Hajer's case of public participatory governance processes.

In the first instance, events such as the annual *INTERSOLAR*, *EU-PV SEC* and *EUROSOLAR* can be considered celebratory in the way they function as promotional events, acting as technology showcases and bring together a wide range of solar sympathizers from across the sectors. While the former have a much more explicitly industry-orientated focus, *EUROSOLAR*'s European Solar Prizes award ceremony is a promotional event that recognises the "outstanding service to the application of renewable energies" of a selection of municipalities, companies, and individuals (e.g. activists, engineers, architects) (Fundación Tierra 2010. **#B79**). In 2009, *Fundación Tierra* was awarded the *EUROSOLAR* prize for 'local associations' its Solar Guerrilla campaign. This resulted in substantial media coverage for the non-profit, with the result of attracting financial assistance to the campaign such that the photonic kit can now be sold at 120 Euros below its original price (685 compared 805 EUR) (Fundación Tierra 2009. **#B75**).

An entirely different type of event, the *debate*, brings together stakeholders that do not necessarily share a favourable disposition to an issue. A range of such events were being held in Paris before and at the time of research, as the city's *Plan Climat* was drafted (2006) and the urban spatial development plan was undergoing reform. These *réunions* and *conférences-débats* were taking place in the different *arrondissement*'s town halls as public events in which citizen's were given the opportunity to express their opinions on the content of the climate protection strategy and the directions of spatial reform[31]. Events such as these provide a platform for a diversity of stakeholders to exchange views. The following passage from a London-based event's transcript, the UK's *Westminster Energy, Environment and Transport Forum*'s 'Keynote Seminar' on the directions of UK renewable energy policy is telling of this. The way in which the keynote speaker is challenged by the comment from the audience about his assessment of the renewables industry, emphasises, on the one hand, the distinction between events and texts, in terms of type and speed of verbal exchanges and style of argumentation they each enable; and on the other hand the much more confrontational character of debates as opposed to celebratory events:

> Keynote speaker:
> [Dr John Constable (Policy Research Director, Renewable Energy Foundation)]

[31] Interestingly, in the Parisian cases the events were transcribed and made available to the public on the internet; the transcript of the London event, however, was password-protected and only circulated to those who attended.

> Irrational policy has sheltered the technology from market realities, and the products driven in were inferior and the installations sloppily designed… There are product quality issues, O&M [operation and maintenance] concerns, lack of realism about curtailment… it is almost completely unadressed by the industry…

Comment from the audience:
[Rupert Blackstone, Associate at Arup]

> I would like to start off countering what Dr John Constable had to say, as I felt he misrepresented the renewable energy industry… he did not however mention the success of the Japanese photovoltaic programme, the German photovoltaic programme… What would his views be on these?
> (House of Commons, Westminster Energy, Environment and Transport Forum, *Keynote Seminar: The UK's Renewable Energy Strategy*. 26 November 2008. **#L59**, transcript page 65)

A third type of event that can be distinguished from celebrations and debates is the *informative* event, which is aimed at informing diverse parties about the desirability and feasibility of PV. Events such as the series of 'Café Energie', the annual 'European Solar Days' and the one-off Mayors and Councillors solar conference[32] (May 2009) are the most prominent examples all of which took place in Paris over a relatively short course of time[33]. The *Café Energie* on solar energy are two events that took place one year apart on the architectural feasibility of PV in Paris and a follow up event one year later about developments that had since taken place in Paris' spatial development policy reform. Both events were organised by the Parisian Architecture Council (*CAUE*), a public advisory body, and *EDIF*, a non-profit environment and energy agency formally charged with energy advice in several of Paris' arrondissements. They were public events open to anyone in a relatively informal setting (a houseboat used for entertainment events on the Seine) and involved a panels of experts (such as architects, energy advisors, and other built environment and policy professionals) that made themselves available for questions from the public. In

[32] *Conférence des Maires et élues pour le solaire.*
[33] The lack of evidence of Barcelona-based events and the non-specificity of London events is not straightforward, however it could be attributed to the timing of the research. In Barcelona/Spain PV has already become much more 'mainstream' than in the other two cities, and in London/UK PV generally falls under the broader banner of micro-renewables.

contrast, the Mayors and Councillors solar conference, organised by a private for-profit solar energy company targeted explicitly professionals and elected public officials to provide information and to persuade these stakeholders to implement solar energy (thermal and PV) in their localities across France. The setting was much more formal (see Figure 4.12) and participants were made to pay a fee of 140 Euros for attending. Money, or rather finance in general is the final architectural form that is discussed as performing PVs sociomateriality.

Figure 4.12 Conférence des Maires et élues pour le solaire, 16 May 2009, Paris
(Source : author's)

4.3.4 Finance

For Latour (1990) 'money', in its various forms, is significant because it is establishes relations between different actors. Money may gather different 'places and times' without changing its shape (Latour 1990). Callon (1991) argues it is not just the case that money 'flows' along predefined pathways between actors but rather that money is a materially durable type of communicative medium (i.e. an immutable mobile) which is itself constitutive of relationships. For Law (2007), from a post-ANT perspective, this means that money performs the relationships it constitutes. Importantly, in the context of PV, the commitment of finance as a way of bringing into being technological relations is an option available only to the fewest actors. Whatever their precise purpose only relatively well-resourced and institutionally powerful actors (mostly national governments) are able to leverage money. Monetary finance committed to PV can be seen as engendering three distinct sets of sociomaterial realities of PV, which differ according to the spatial and temporal pattern of relationships they perform.

In the first instance, governments at different scales may directly commit a nominal amount of finance to PV, for instance for research and development (R&D) or demonstration purposes (DTI 2004; DTI 2006). These nominal amounts can be seen as *cascades* of finance, "money trickling down" (Renewables Development Manager, *EST*, Interview, London, November 2008) from one central organisation to other parties. Cascades are unidirectional flows of finance in which the passing down of money is essentially hierarchical, from a powerful and well resourced actor, i.e. mostly national governments, to diverse sets of other actors who are recipients. Figure 4.13 is a representation of the cascade effect produced by these so-called 'grant schemes' – e.g. *Domestic Photovoltaic Field Trial* (*DFT*), the *Large Scale Building-Integrated Photovoltaics Field Trials* (*LS-BIPV FT*), the *Major PV Demonstration Programme* (MDP) and the *Low Carbon Buildings Programme* (*LCBP I+II*). Each of these programmes, running altogether between 2000 and 2010, provided a percentage amount of capital grant funding to different types of individuals and organisations wishing to install PV on their buildings[34]. Grant schemes are essentially a series of 'one off' transactions, which conclude in each case once the financing actor has honoured their commitment to the recipient. A rather more *cyclical* form of financing is where money is rewarded not for the installation of systems (as with grants) but to the generation of PV power, such as through 'feed-in tariffs' (FITs). The principal actors channelling finance are, again, mostly national governments, but FITs are qualitatively different from capital grant funding as they do not involve substantive amounts of public money. Rather than government-funded, they are financed through a levy on electricity consumer bills, as electricity suppliers re-distribute the costs of the solar power they buy to their wider customer base[35]. Thirdly, *cashback* may be granted through tax breaks (again, by national governments) to PV system owners. These can affect the capital expenditure of system costs, as for instance, the French tax break on PV capital (system cost)

[34] In the UK grant funding has also been made available through non-governmental, charitable 'funding pots' such as by the Ashden Trust and the National lottery.
[35] Although, it should be noted that the Spanish case is an exception as the Spanish state already subsidizes grid electricity through the 'deficit tarifario', and is thus itself more financially implicated in the FIT than is usually the case.

investment (*Crédit d'Impôt*, see Figure 4.14). Cashbacks are neither cascades nor cycles strictly speaking, but may work in concert with either.

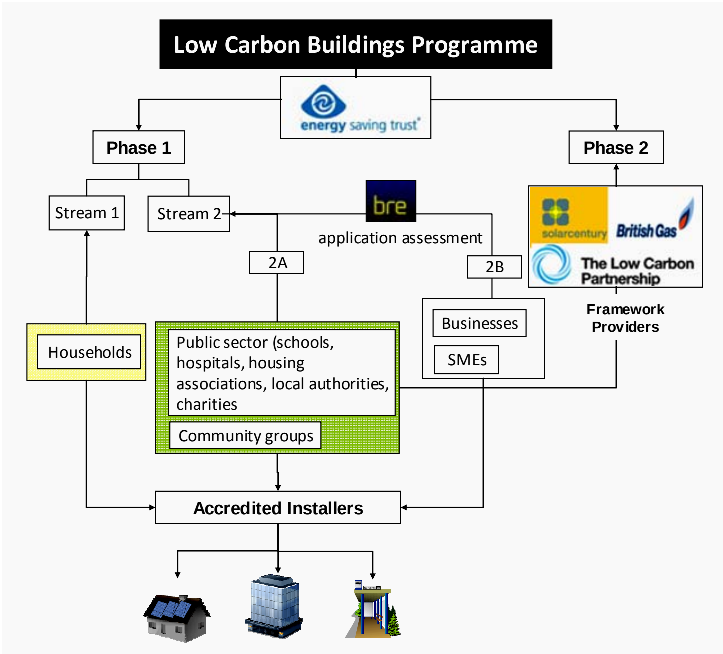


Figure 4.13 Financial architectures I: cascades
(Source: author's)

It is argued that finance, whether through cascades, cyclical exchanges or cashback are enacting a particular sociomaterial reality of PV. Through channelling funds towards particular actors and types of PVs as opposed to others these three financial architectures work to perform particular realities of urban PV. For instance, the UK Major PV Demonstration Programme subsidized the capital costs of PV systems up to 50% and 60% for small scale (domestic) applications and medium-scale non-domestic systems on public, commercial or community premises, respectively. This effectively constitutes an enactment of a version of PV that translates an aspiration of PV in the built environment owned by 'non-traditional' generators into practice. It constitutes a strong contrast to the Spanish FIT which has for a long time served to bring about large-scale (mostly non-built environment) systems that are more lucrative as they deliver relatively greater amounts of kilowatt (or even megawatt) power – in general, FITs' precise formulation differ from country to country (for instance, in contrast to Spain the French FIT strongly favours building-integrated systems to standalones and superimposed rooftop panels). Crucially, designing financial support schemes and articulating particular levels and duration of funding contains both implicit and explicit choices about *who* or *what* is to count as eligible for funding. This implies that viewing finance as a means to 'protect' emerging technologies, as proposed by the *SNM/MLP* innovation literatures, is rather misplaced. As explored above, financial architectures do however make particular realities of PV more likely than others.

1 2 3

Figure 4.14 Financial architecture II

(Source: [1]ADEME 2009, *Les aides financières habitat*. **#P3**; [2]ADEME 2008, *La production d'électricité raccordée au réseau*. **#P2**; [3]Mairie de Paris/ADEME 2008, *Copropriété Objectic Climat*. **#P88**)

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Up to this point the chapter has developed an understanding of technology as consisting of a sociomaterial architecture of utopical techniques. As an overview, Table 4-2 summarises the analysis of the different mediating roles of these utopical techniques and the relations they enact. While it is useful for analytical purposes to interrogate the relational work each of these perform in isolation, in several instances in Sections 4.3.1-4.3.4 it has been suggested that utopical techniques are in fact more often than not intimately conjoined. The purpose ascribed to artefacts, for instance, is frequently made public through being circulated in a range of texts, which in turn serve to advertise events and the availability of financial architectures; while finance techniques often make possible the installation of artefacts, and texts and events serve as forums for celebrating, debating and informing about the utopical merits of technologies such as PV in the first place. The relationship between different utopical techniques is the theme of the following Section 4.4. It analyses the way in which architectures are combined in the practice of converting utopical aspirations into actual states of affairs. This, it is argued, gives rise to several distinct 'utopics'; a term that is used to denote a set of spatial and ontological (that is world-building) strategies through which actors attempts to convert their aspirations about desirable outcomes into practice.

Table 4-2 Gathering effects of architectural techniques

Utopical technique	Mediating role	Relations enacted	Example
Artefacts	Inscribed with intention	Public and participatory spaces	Systems and displays of municipal PVs participatory projects
Texts	Representations that gather entities in the space of the document and circulate between actors	Intention to act, causal linkages between intervention and outcomes, persuasion	Strategic policy documents, technical reports, promotional brochures and flyers
Events	Assemble selection of actors in physical space at particular time, enabling enable face-to-face verbal exchanges and networking	Spatially and temporally contained celebrations, debates and information	Prize giving ceremonies, public debates and Q&Q sessions
Finance	Promote otherwise unlikely outcomes through monetary incentives	Cascades and cash back, cyclical return cycles	Grant schemes, tax breaks and feed-in tariffs

4.4 Utopics of innovation in urban PV

It remained largely implied in Section 4.2 how *Fundación Tierra*'s photonic kit GS120, *Solarcentury*'s C21e tile and the glazed PV roof of the ZAC Pajol promoted by the *Mairie de Paris* not only embody different aspirations but, crucially, also constitute different kinds of interventions. While the focus was previously on these actors' utopian aspirations – eco-empowerment, carbon reductions and livelihoods – and the constitution of a common but heterogeneous sociomaterial architecture, this section is concerned with how utopical techniques are combined and conjoined in actors innovative practices. Innovation, Chapter 5 (Section 5.4.2) proposed, involves making material, or 'spatialising', aspirations about desirable future outcomes. The notion of utopics was introduced to conceptualise the relationship between aspiration and material consequences; that is, to frame the process of converting visions about desirable states of affairs "from the nowhere of the imagination" (St John, web-based), into reality (Hetherington 1997; Marin 1984). 'Utopics' signals a concern is less with the precise contents of aspirations rather than ways of spatialising these. It implies that it may be the case that kindred aspirations are achieved by different means, while diverging visions can potentially be brought about through similar interventions. As such utopics should be understood as distinct 'modes of mattering' (Law 2004b) through which different actors attempt to act upon the status quo.

Understanding innovation as 'utopical' in nature introduces a spatial and normative sensitivity to conceptualising innovative processes that enables a different kind of technological account than is prevalent in existing frameworks in innovation studies. While the prevailing *SNM*/*MLP* framework has tended to focus on the orchestration of 'experimental' spaces by public policy and private sector actors, scholars within the broad discipline have already noted that in practice a diversity of actors attempt to innovate (Seyfang and Smith 2007; Späth and Rohracher 2010; Smith et al. 2010). What has up to date lacked, however, is a more sophisticated engagement with the different forms of innovative practice of different actors. As the previous sections already hinted at, there are a diversity of actors engaged in promoting PV (from the public, private and third sectors), and they are doing so using not only artefacts but also texts, events and finance to attempt to gather a diversity of social, material, spatial and temporal relations for their particular purpose. Utopics as explored over the course of this section are not properties of actors as such and it is conceivable that the same actor may potentially enact a number of utopics that achieve desirable outcomes through different means. It is argued in this section that different utopics work according to relatively distinct logics: *leadership*, for instance, is based upon exemplary practice, while *critique* provides a perspective on the status often through offering up alternatives; *synergy* involves the forging of mutually beneficial alliances across heterogeneous groups of actors while *problem-solving* enables others through generating knowledge and capacity, offering advice and guidance that enables others. This is not to suggest that these are the only ways in which actors may innovate; however they are the four modes that were identified in this study based on how different utopical techniques combine into diverse modes of mattering.

4.4.1 Leadership

> Big cities must modify the way they manage transportation, their consumption patterns and their energy sources… From now on, far-reaching change is required to achieve the necessary transformations… And Paris?... the third axis of our policies concerns renewable energy, with a clear aspiration: that they should contribute 25% in our overall energy consumption. For instance, 200,000 metres square of photovoltaic panels will equip several eco-neighbourhoods in the capital.

Figure 4.15 Municipal leader

(Source: Delanoë 2009, *Speech at Climate Change Leadership Summit, Copenhagen 2009*. #P32)

The *Mairie de Paris*, just as the *Ajuntament de Barcelona* and the *Greater London Authority*, has developed an urban policy which features sustainable development, and more recently, 'climate change' as a cross-cutting policy priority. However, delivering urban renewable energy in Paris is fraught with difficulties deriving, amongst other things, from the city's strict development guidelines (summarised by the notion of *patrimoine* – architectural heritage, see Sections 5.2 onwards). Delivering PV in Paris is marked by trans-scalar governance conflicts between the jurisdiction of municipality and the nation state upon Paris' built environment, owing to the fact that a substantial part of the city falls under the national heritage building code. As listed conservation areas, installing PV requires the authorisation of national state civil servants, who issue binding planning permission (and often refusal). Inconsistencies between the Mayoral aspirations of the 'sustainable city' enshrined in the 2009 *Plan Climat* (a strategic document on climate change mitigation and adaptation) are such that the existing urban spatial development plan (*PLU*[36]) was effectively incompatible with the Mayoral climate protection aspirations (until its reform, see Section 5.4).

Through orchestrating events such as the local *réunions* and *conférences-débats* on the *Plan Climat* in the city's *arrondissements*, and speaking himself at the 'Local Government Climate Change Leadership Summit' in 2009 (a side event to the United Nations Conference of the Parties (COP)), the multi-lateral negotiations on climate change), Parisian Mayor Bertrand Delanoë positioned himself as municipal innovator, reformer – and leader. During the latter, Delanoë presented Paris as an ambitious, sustainable capital in a wider community of aspiring sustainable cities engaged in the fight against climate change. In this light, Mayor Delanoë's 2006 statement concerning the aspiration to install 200,000 square meters of solar PV artefacts on Paris rooftops was no coincidence. The director of *CLER* explains its rhetorical value:

> We've had grand declarations by Monsieur Delanoë about a year and a half ago, that he wanted to turn Paris into a solar capital. I'm always a bit embarrassed when I speak to my German colleagues, I mean, it makes me laugh, rather. But then, there's something to be said about this. It's ludicrous from the outside, but then when seen from the inside, obviously Paris won't be a solar capital, at least not in the coming years or decades I'd say [laughs] but, one of the difficulties is to get it into peoples' heads, mentalities, that Paris has a problem of *patrimoine*, it prevents her from moving with the times.
> (Director, *CLER*, Interview, Paris, May 2009)

Besides the political statement of '200,000 square meters', the Parisian Mayor launched a series of solar PV initiatives. The modernist installations at the ZAC Pajol (18th), the 'eco-neighbourhood' of Clichy-Batignolles (17th), and the regeneration of the old market Carreau du Temple (3rd) are high profile PV initiatives through which Delanoë signalled his unwavering aspiration to reconfigure the Parisian urban landscape along more 'sustainable' principles. They can be seen as manifestations of an utopic by which the Mayor's reformist ambition are spatialised as a way of reconfiguring the historically deeply entrenched development guidelines in light of the new political imperatives related to climate change. Key to Delanoë's mode of mattering are the architectural techniques of

[36] *Plan Local d'Urbanisme.*

events and artefacts, alongside with a range of text-based promotional documentation circulating about these.

Such a leadership utopic is similarly strongly displayed by the *GLA*. Several PV showcases on administrative and iconic buildings feature as a visible component of former-mayor Ken Livingstone's climate protection-orientated urban development vision. Urban scholars Bulkeley and Schroeder (2008: 10-11) note how, under Livingstone's leadership, London was positioned as "setting an example to other 'global' cities on climate change"[37]. As a GLA interviewee involved in several 'flagship' PV projects confirms, the 'political capital' acquired through PV extends far beyond the city in terms of an international leadership role:

> You can't stand up in the world economy and tell some Indian commissioner he needs to do something in his country when you're not doing it yourself… we know it may not be perfect right here… but we've still done it and shown it can be done… So whether it's India or China or the whole of Africa, you know, once you've done it yourself, then at least you have the right to stand up and say, we know what we're doing.
> (Project Manager/engineer, *LCCA*, Interview, London, November 2008)

As the interviewee implies, the flagship projects serve as visible and tangible symbols of proactively 'leading by example'. Leadership utopics here can be taken as characterised by a spatial practice through which artefactual examples are set for others to follow, circulated through events and texts which advertise the leader's experiences of 'having done it'.

While a leadership utopics is common to the three municipal authorities in Barcelona, London and Paris, it is also an utopical form present in the activities of other, non-public actors. *Fundación Tierra*'s Solar Guerrilla campaign, for instance, is also positioned as an exemplary practice that others should follow. As the 'Solar Guerrilla Manifesto' states,

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[37] "*international leadership* has been a key element of London's strategy. Together with The Climate Group, in 2005 London's political leadership established the C20 network of 'global' cities and bought together key cities for a summit on responses to climate change to coincide with the 2005 G8 meeting." (Bulkeley and Schroeder 2008: 10)

[37] To this day the system is not rewarded with the national feed-in tariff, but the system was in fact reconnected following the entry into force of the Kyoto protocol, based on the foundation's principled aspiration to 'refund' some of the electricity it has drawn from the grid.

> We want to be exemplary in our households by generating electricity using clean and renewables sources such as the sun, the wind, water or biomass… we, the Guerrilla Solar of Planet Earth, are committed to use safe and certified technologies that do not harm our neighbours, the workers in the energy sector or our environment… above all, the Guerrilla Solar is a movement of civil awareness and compromise with future generations. (Fundación Tierra 2009, *Manifiesto de la Guerrilla Solar del Planeta Tierra.* **#B73**)

However, besides this leadership component, the Solar Guerrilla, and the majority of activities of *Fundación Tierra* are better captured by considering them as a different form of utopic, which is much more confrontational in its critique of the status quo, working through overtly subverting rather than purely providing leadership towards alternatives.

4.4.2 Critique

"The Solar Guerrilla module, a household appliance that puts up a fight… Pere Soria…: a Guerrilla on duty"

Figure 4.16 Transgressive activist: the Solar Guerrilla

(PHOTON Magazine 2009, *Panorama: Los Guerilleros del Sol*. **#B121**)

The dominant form of utopical innovation of *Fundación Tierra* differs substantially from the leadership utopics of the *Mairie de Paris* and the *GLA*. The Barcelona-based non-profit began its renewable energy activities in 1998 staffed with a series of individuals with an environmental activist background. Their involvement with solar power and PV specifically initiated with a PV installation that was one of the first in small-scale terrace installations seeking grid-connection in Spain, in what was then (and largely still is) a highly centralised electricity system. While the challenges encountered by the pioneering activities of the *Fundación* are more fully explored in Chapter 5, for the present purpose the mode through which the organisation has sought to bring about change is relevant in terms of the way it has spatialised aspirations for energetic sustainability. As one of the first small-scale PV systems to connect to the national grid the *Fundación* set a technical and legal precedent with the local utility's engineers and the Spanish High Court, respectively. Through the latter a particular transgressive aspect of the *Fundación*'s mode of intervention becomes evident. The organisation appealed to the High Court by denouncing the substantial administrative barriers facing small scale power generation in Spain (see Section 5.2.1). When this did not lead to changes in the regulatory system (see Section 5.4.2), the organisation declared a 'solar strike' by disconnecting their system from the wider grid[38].

Invariably, its activities serve to unsettle, whether the organisation targets the powers that be or civil society more generally. Contrary to the (often, although not necessarily) more 'high level' arena of a leadership utopics, and its mode of 'leading by example' the organisation expends much of its energy on involving civil society in renewable energy matters, through for instance, educational and leisure campaigns. For instance, the 'solar kitchen' on its roof terrace, initially serving to link 'friends and family' into becoming conscious about energy issues, was extended into large 'solar Paella' events (see Figure 4.17) that draw citizens of all ages. This and the 'solar chocolate' stand are used to showcase the power of the sun and that cooking with solar is a real alternative in Barcelona, and not only in places where there is no other option, as in some regions, for instance, where solar cookers are the norm. Similarly, the *Ola Solar* ('Solar Wave') is a one-off participatory PV installation which brings together 140 individual investors, who each receive yearly dividends of roughly 100 Euros from the income generated by the sale of electricity to the utility under the Spanish feed-in tariff[39] (each having contributed between 1,000 and 3,000 Euros to the (43.7 kWp) systems' costs). While not without challenges, the utopics of the *Ola Solar* transgresses against citizens' established (dis)engagement from energy infrastructures. It does so,

[38] To this day the system is not rewarded with the national feed-in tariff, but the system was in fact reconnected following the entry into force of the Kyoto protocol, based on the *Fundación*'s principled aspiration to 'refund' some of the electricity it has drawn from the grid.
[39] The investment for the system was 301.000 € for 43,7 kWp of installed capacity, generating an estimated 51.000 kWh every year.

as it turns regular citizens into 'shareholders of the sun' and an otherwise energy consuming municipal market into an "initiative of popular capitalism" (*Fundación Tierra* 2007. **#B74**).

1

2

3

"The dishing out of chocolate is accompanied by an explanation on the use of renewable energy and environmental sustainability."

Figure 4.17 Solar wave, paella and chocolate

(Source: *Fundación Tierra.* [1]**#B81**; [2]**#B87**; [3]**#B86**)

Besides connecting the everyday experiences of Barcelonans to issues of energy sustainability, one of the chief concerns of the *Fundación* remains to this day an expressed aspiration to expose and undo the systemic bias against non-centralised power generation in Spain, in order to bring about their utopia of eco-empowerment through energy sustainability. The Solar Guerrilla campaign currently constitutes the *Fundación*'s most transgressive form of activism. Here PV is used as a way of spatialising the *Fundación*'s aspirations of broadening participation in renewable energy and pressuring the Spanish government for regulatory change. Specifically, the sort of 'plug-and-play' mode of generation, by which PV is simply connected to the grid without prior authorization from the utility is currently not legal in Spain. Neither, however, is it illegal. The sub-kilowatt capacity of the photonic kit means that it does not qualify as an electricity generator in legal terms. The *Fundación* thus takes advantage of this legal loophole by which the sort of micro-scale electricity generated by solar guerrilla panels is situated in a 'grey area'. As such, the photonic kit GS120 constitutes a mode of innovation that constitutes the basis from which *Fundación Tierra* gathers the roofs and terraces of a range of prospective solar *guerrilleros* to transgress against the Spanish administrative system.

As suggested already in the previous section, the *Fundación*'s activities are not purely of critical character, with a component of a leadership utopic found in their pioneering efforts and the Guerrilla campaign. That different forms of utopics co-exist is not unusual, however it should be noted that they work through different means and by gathering different relations. For instance, in the *Fundación*'s case PV technology and its associated utopical architecture brings on board not only citizens (through a text- and artefact-based utopics of leadership) but also public authorities (through materially playing with the GS120 a-legality). And there is yet more to the campaign's success besides its blending of leadership with critique. This is characterised by another, third form of utopics, which is an ability to create *synergetic* relationships between actors of very different kinds, including private sector actors (a relatively small PV panel manufacturer, *Gahelios*, charged with the manufacture of the GS120). This third form of utopics is further explored in the following section using the example of the London-based 'for-profit' PV company, *Solarcentury*.

4.4.3 Synergy

This century has to be a solar century if we're going to survive the threat of climate change. My name is Jeremy Leggett, I'm Chief Executive of a solar energy company in the UK, and our purpose is to make a big difference in the fight against global warming…

…It's very important, I think, that business people plug into the emerging concerns of society. If it's all, at the end of the day, just about making money, we will not save this planet. We will go under.

It's vital to get out of bed everyday and try as hard as you can to contribute to the forces that make the breakthrough towards survival, sustainability and some kind of hopeful future for human civilisation on the planet.

> It's just one of these modern success stories. They've marketed themselves well… they have set up some clever schemes. I suppose there are just some companies that are good at it, a bit better, you know [laughs] they have better ideas… they are achieving something slightly above the average status.
> (Energy Advisor, *CEN*, Interview, London, November 2008)

Figure 4.18 Eco-preneur: Jeremy Leggett, CEO Solarcentury

(Source: Solarcentury website, *Solar people*. #L198)

Solarcentury is the UK's largest and most active solar company in the downstream market segment that operates at the product, project and installation level. Unlike the public body of the *Mairie de Paris* and the non-profit *Fundacion Tierra*, it is a private sector 'for profit' company. Its self-understanding, as outlined in the 'About Us' section of its website, fits with existing understandings of 'eco-preneurs' in the literature, as a combination between "entrepreneurial zeal" and "green motivations" that "transcends the usual tensions between business and the environment" (Beveridge and Guy 2005: 665):

> We envisage solar tiles on the roof of every building… We design innovative solar products, work with architects and developers to incorporate solar technology into the built environment and offer support and guidance throughout the entire planning and development process. Solarcentury is a solar energy company with a purpose: to make a big difference in the fight against climate change.
> (Solarcentury website, *About us*. **#L190**)

As with *Fundación Tierra*, the utopic enacted by Solarcentury is partly one of leadership, applied to its self-understanding of a company “with a purpose” amongst other private sector companies which by implication, may lack (an environmental) one. It also displays elements of critique in seeing itself as a “very vocal business, not scared to say what it thinks about the state of the world, policy, government policy, be it central or local, planning rules and things like that” (Project manager, *Solarcentury*, Interview, London, November 2008). However, its chief mode of mattering which makes it the successful business that it is of a different kind; namely that of creating (business) links where there previously were none. This is different from simply gathering diverse actors into a relationship with *Solarcentury*. Synergy refers to the mutually reinforcing, beneficial and seemingly self-sustaining relations that *Solarcentury* establishes between themselves, government, private sector corporate actors, other smaller solar installers and a growing customer base. An utopic of synergy such as *Solarcentury*’s requires hard work and a diverse portfolio of activities; including a range of ‘in-house’ (artefact) products (the C21e solar tile, amongst others), government contracts, corporate social responsibility (CSR), (financial) sponsorship and good working relationships with other companies who are, at least formally, their competitors.

Solarcentury’s utopics of synergy can be understood to have taken off with two related events. First, having been commissioned as PV consultants on the ‘CIS Tower’ in Manchester, a large and high profile project, brought the company in contact with a range of actors from the construction industry, as well importantly the Cooperative Group. Secondly, *Solarcentury* was awarded a so-called ‘framework contract’ by the UK government for managing the PV branch of one of its series of government-funded grant schemes. This in itself was a source of synergy, as the following interviewee from a London-based non-profit energy agency explains:

> It means they give work to other installers… it means that they get bigger, they get more known and people have no choice but to go through them. Even them people who were doing it on their own are putting some work into them. It’s a good business model. Clever people. [laughs]
> (Energy Advisor, *CEN*, Interview, London, November 2008)

From these two events ‘solar4schools’ took shape, a nationwide initiative aimed at installing small PV systems on primary and secondary schools for their educational value (see Section 6.6). The ‘solar4schools’ programme is representative of the ways in which *Solarcentury* succeeds in bringing into synergetic relationships a set of very heterogeneous actors:

> we have a good business relationship with the Cooperative Group. They wanted to do some projects for renewables in schools, and we said ‘look, we’ve applied for this framework status, if you come with us you can double the power of what your money can do’. On their own, the money would have installed systems on 50 schools, with this status, and with access to this money we did 100 schools. The Coop were happy, the government were happy, everyone turned up at the hundredth school and took the credit for it. We took the credit for doing it, the coop took the credit for putting half the money out, and the government took credit for giving the other half of the money out.
> (Project manager, *Solarcentury*, Interview, London, November 2008)

Solarcentury’s solar4schools programme is an enterprise that is positive for both the earth and *Solarcentury*’s business portfolio. It is in many ways an open ended set-up that promises to provide the organisation with a project business income for years to come. As the promotional video states, “although one hundred schools seems like a lot, it’s just the beginning. We want to see solar on all twenty five thousand”. There is, it seems a large market that *Solarcentury*’s eco-preneurship may yet tap. The media coverage that ‘solar4schools’ received raised the interest of other potential CSR actors, such as Barclaycard, who become further corporate sponsors of *Solarcentury*’s through their ‘green’ credit card product[40].

From an ideological starting point of wanting to do ‘the right thing’ and in particular the lack of a ‘specific business model’, the organization has over the years expanded its portfolio of activities across a diversity of areas. Perhaps *Solarcentury*’s synergies are as effective as they are because synergies are frequently of financial character. Its commercial products bring it into relations with clients small (domestic) and large (contractors), it maintains good working relationships with other solar installers, who use the company’s products and sometimes take part in *Solarcentury*’s contracts; while government and corporate actors channel financial support for PV through the

[40] This includes a promise to donate a certain amount of profit made to ‘green’ projects.

organisation. As a result, *Solarcentury* has become a central actor in a loose network – consisting of local and national governments, the PV industry and smaller installers, NGOs and quangos, domestic households, communities and a range of corporate organizations, as both clients and funders – upon whose resources it can draw. Even Solarcentury's competitors are largely included in this resource base as they frequently do not see themselves as standing in direct competition with *Solarcentury*'s activities:

> Interviewee: we're non-profit but we're still competing with people for money and bids, and tenders…
>
> Anne: *Solarcentury* has launched a solar for schools programme, does that conflict with the project you're running?
>
> Interviewee: yea but… it's all good stuff. [shrugs, grins slightly]
> (Managing Director, *Carbon Descent*, Interview, London, November 2008)

During interviews with a series of non-profit organisations in all three cities it emerged quite clearly that these types of organisation predominantly engages in quite a different form of utopic than *Solarcentury*'s commercially orientated synergistic mode of innovation. While *Solarcentury* is constantly engaged in harnessing complementarities between its own and others' interests, the final form of utopics is one in which the business savvy creativity characteristic of a synergy utopics is replaced with a form of intervention that is orientated towards enabling others through *problem-solving*, by means of project advice and technical analysis.

4.4.4 Problem-solving

A final form of utopics that is present across a range of different actors' innovative interventions is captured by the way in which it is less characterised by leadership, critique or synergy, than by the notion of problem-solving. In some ways the 'juggling' work of the interviewee quoted above is akin to *Solarcentury*'s creative synergising between a diversity of actors, urban spaces and materials, however, an important difference is the way in which this is generally understood in terms of an activity of problem-solving which is tied up with 'a great deal of work'. In Paris three main local energy agencies organisations operate across the cities 20 *arrondissements*. These

'Energy Information Spaces' (*EIE*[41]) have bureaus across the city in which citizens can visit and phone up for advice on energy matters, ranging from energy efficiency and saving to the installation of renewable energy technologies on their buildings. The Parisian *EIE*s were set up in 2001 by the national French Agency for the Environment and Energy Management (*ADEME*[42]) and they essentially constitute a national network of several hundreds of energy agency advice centres across the entire country. Besides advisory services, in Paris the *EIE* are also key vehicles through which urban climate protection measures are carried out. Specifically, the EIE are part of delivering the *Mairie de Paris's* 'Copropriétés Objectif Climat' initiative, which is an initiative seeking to retrofit shared ownership buildings (*copropriétés*), which account for roughly over half of Paris's building stock, with energy efficient upgrades.

we have to put in a great deal of work… We really have to convince them, because it can go either way… So I talk to them a lot, so they get to know me, so that they feel they can approach someone with a face. You know, there's a very human side to this. So we have to juggle all this.
(Energy Advisor, PASU, Interview, Paris, May 2009)

Figure 4.19 Espaces Info Energie in Paris

(Source: Mairie de Paris 2007. **#P4**)

[41] *Espaces Info Energie.*
[42] *Agence de l'Environnement et de la Maîtrise de l'Energie.*

As the *EIE* set-up illustrates, problem-solving is a form of utopics that may work across the activities of individual organisations. It is expressed through what Medd and Marvin (2008: 289; Moss 2009) have called 'strategic intermediation', which refers to a form of 'fluid' work that sets out to perform an integration of diverse territorial, institutional and ecological spheres of activity by translating between priorities and organisational realities; often through working across and beyond formal institutional structures. The *EIE* advisors, for instance, frequently deal with "very messy problems" such as projects that involve *copropriétés* [multi-ownership buildings] – "very long to implement, a really lengthy enterprise" (Energy Advisor 2, *EDIF*, Interview, Paris, May 2009). Another energy advisor, this time in Barcelona, also characterises her work as consisting of a problem-solving routine. In her case it is the context of a rather convoluted system for becoming eligible to receive the national financial support for PV that constitutes the problem:

> what is lacking is an easy system without all the paperwork... it creates us a lot of hassle especially in urban areas, you have a few square meters here and there…
> To motivate individual generators, or someone who takes on the burden, who has the capacity to find the information [about roof space and orientation], fill in the forms, rents the roof, connects to the grid, reaps and hands down the FIT.
> (Energy Advisor, *Ecoserveis*, Interview, Barcelona, March 2009)

On the one hand, thus, an utopics of problem-solving works 'on the ground':

> in terms of the process of helping people actually get the stuff on, that's what we help them with… all of these different things, hurdles that you have to overcome and often communities themselves don't have the expertise to do that, they need support doing that.
> (Energy Advisor, *CEN*, Interview, London, November 2008)

However, while there are several organisations that carry out 'messy' project management, other problem-solving utopics may take place at a level that is removed from the 'leg work' of local energy agencies. For instance, in Barcelona Regional S.A. is a public-private regional development agency which has been involved with PV in a 'strategic' capacity. As a "technical and solution-orientated consultancy concerning matters of urban development and territorial strategy" (Senior

Project Manager, *Barcelona Regional*, questions via email, April 2009) the organisation was involved in the modelling work that went into the text of Barcelona's 'Energy Improvement Plan' (PMEB 2003) which set estimations of the technical potential for PV in Barcelona (however, a contested calculation, as Section 6.4 explores). Other problem-solving activities may be even more 'high level' in the sense of being removed from the project level. For instance, the London-based market research consultancy *Solarbuzz*, is "fairly global in nature… a sort of global helicopter-type view" (Vice-president, *Solarbuzz*, Interview, London, November 2008). As the organisation's Vice-President explains,

> our main report is called Marketbuzz…… and we analyse three scenarios for the forecast outcomes for the next five years… we follow that up in June with three regional reports…essentially greater details on policy and forecast discussions… those reports sell into the PV industry, materials supplies, equipment supplies, financial community. And the other thing we do is task-specific consultancy work for various types of companies, new entrants and manufacturers wanting to do different things in different ways.

Evidently, *Solarbuzz*'s problem-solving is different from that of the *EIE* and other local energy agencies, such as *Ecoserveis* and *Creative Environmental Networks*, involving the production of texts at particular points in time rather than working through the use of PV artefacts and promotional campaigns. Most strikingly perhaps, it is 'for profit' (i.e. PV here is a technology for livelihoods, rather than one for carbon reduction or eco-empowerment). While they share in common that all three address the identification and resolution of problems, a problem-solving utopics according to different aspirations may have very different consequences for innovation in general, and implication for others seeking to make a difference. For instance, while I am myself subscribed to *Solarbuzz*'s newletter I have been unable to access a single 'Marketbuzz' report. The following exchange took place during the interview with *Solarbuzz*'s Vice-President:

> Anne: those reports look really interesting. I'm subscribed to your newsletter but those reports are slightly out of my budget.
>
> Interviewee: [laughs] they probably would be, yea.

The lack of access to the report I experienced stands in stark contrast to the ease with which I was able to gain in depth information on the activities of different local energy agencies. This draws attention to that the materials of utopics are very different depending on whether local energy agencies involve citizens through project-based initiatives, such as the 'Copropriétés Objectif Climat' in Paris, or consultancies such as *Barcelona Regional* and *Solarbuzz* who monitor and forecast through publishing strategic documents and market analyses. One may yield actual PV installations (if a project succeeds) and the other, weekly internet-based newsletters and industry reports that can be purchased for prices 'beyond my research budget'. Thus, while both are effectively geared towards promoting PV, there are substantial differences in effect between the 'leg work' of carbon reduction and more strategic problem-solving utopics for livelihoods. This begins to draw into focus the way in which different ways of spatialising aspirations about PV may have very different spatial and material implications in practice.

Importantly, while one actor may be performing more than one utopic, this does not mean that different actors' utopics will be necessarily compatible. The relationship between different actors' utopics in terms of how well they convert 'sustainable' aspirations into reality is the theme of Chapter 6. At present, however, the chapter concludes with a discussion of the emergence in urban PV in Barcelona, London and Paris, respectively. The following section uses insights from the previous sections to provide a material semiotic perspective on each city's PV scene. It does so by weaving the relationship between different actors' utopics over time into three separate accounts of a 'Barcelonan', 'Londoner' and 'Parisian' reality of urban PV. As it emerges, parallel realities of an 'urban PV' are beginning to consolidate, through actors gathering techniques into utopics for converting their diverse aspirations into reality – *within* as well as *across* cities.

4.5 The Emergence of urban PV in Barcelona, London and Paris

Up to this point, the chapter has taken a perspective on urban PV that has rejected taking geographical location as a foundational distinction between processes and practices of innovation in urban PV. The emphasis has been on establishing contrasts and proximity between different actors' practices of innovation: the aspirations for which they use PV's heterogeneous architecture as techniquea, the means available to them and their strategies for converting their aspirations into reality. At present, the chapter uses this relational dissection of technology and innovation to construct a geographically-sensitive account of the emergence of urban PV in Barcelona, London and Paris. Specifically, making use of the previous sections' arguments, the present section provides a more sustained discussion of each city by tracing how the use of the techniques (of Section 4.3: artefacts, texts, events and money) coalesces into utopics (as discussed in the previous section: leadership, critique, synergy and problem-solving), which by virtue of being the spatial conversion of actors' aspirations engender urban PV's various technological realities within and across the cities (as explored in Section 4.2: eco-empowerment, carbon reduction, and livelihoods). In particular, the discussion considers the consequences and compatibility of the different ways in which actors, related to their means and status, convert their aspirations into practice in any particular place.

The discussion centres on three figures (Figures 4.20-22) which are the product of the material semiotic analysis outlined in Chapter 3. Each depicts the PV 'scene' of a city, relating actors engaged in innovation in PV to their utopical techniques. Actors' names (x-axis) are differentiated in terms of their centrality to PV-related processes (through varying font sizes) and in terms of the aspirations they seek to realise (by means of different font colours, with green = eco-empowerment, blue = carbon reductions and orange = livelihoods). Techniques are plotted over time (y-axis) under each actor, and are differentiated by shape (namely, text = square, money = triangle, artefact = pentagon, event = hexagon). The figures also indicate through a shaded area around techniques that techniques intertwine into utopics (differentiated by colour: leadership = pink, critique = green, synergy = yellow, problem-solving = blue). For the purpose of this section these figures feature as representations of findings from the research. It should be noted that they do not aspire to be an exhaustive 'stakeholder map', but rather constitute a product of the tracing of associations that was chosen as a research strategy. As such, they are necessarily selective and situated – however, viewed thus, they generate a context-specific account of the emergence of urban PV that is sensitive to the actors, agendas, and histories that shape an 'urban photovoltaics' in Barcelona, London and Paris.

4.5.1 Barcelona

In Barcelona, the gradual emergence of an urban PV can be traced back to events around the turn of the millennium, when parallel trends at the level of the Spanish state were synergizing with developments that, locally, generated a favourable climate for a technology such as PV. While government understood PV in terms of being a technology valuable mostly for its potential to diversify the economic base of the national economy ('i.e. livelihoods'), then dominated by a housing boom in the south of the country, when the first feed-in tariff was thus established by the government, a Barcelona-based NGO, *Fundación Tierra*, was one of the first non-utilities that installed a small system and sought connection to the national grid. The organization had been vocal about environmental issues since about the time of the multi-lateral Rio Earth Summit in 1992. Based on their aspirations for eco-empowerment – see Section 4.2.1, a blend of environmental and social justice – they had been engaging in a variety of activities (mostly text-based and events) to raise civil society awareness about the state of the environment and society. In parallel, within the city government a critical mass was emerging that saw environmental issues as an avenue through which to pursue urban regeneration. Elections had taken place in 1998 that had brought a number of Green Party members, *Ecologistes en Acció*, into the municipal council which had established the multi-stakeholder and cross-sectoral 'Environment and Sustainability Council'[43]. Shortly after, a seminal environmentally progressive planning by-law, the 'solar thermal ordinance', was approved[44]. It would, however, take another ten years for an analogous 'PV ordinance' to be approved in 2010, around the time at which I came across the case of PV in Barcelona.

The well-rehearsed story of the *Ajuntament de Barcelona*'s 'success' in pushing through some innovative urban policies regarding renewable, in particular solar energy, tends to take as its starting point the 'political decision' made in the Ajuntament plenary to approve the drafting of a solar thermal ordinance (Caamaño Martin 2009).Overall the ordinance, despite some initial setbacks, has been hailed a big success. Besides increasing the use of solar thermal energy in the city almost twenty-fold[45], it was the legal basis for the national Spanish building code (*Coódigo Técnico de la Edificación*). The leadership of the *Ajuntament* in environmental matters is further suggested by its adherence to some the decade's most important environmental commitments (such as the Heidelberg Declaration, Aalborg Charter, and the Covenant of Mayors). With respect to PV, the main municipal strategy, demonstration projects in municipal buildings, began in 2000

[43] *Consell Municipal de Medi Ambient i Sostenibilidad.*
[44] This established the requirement for new buildings and those undergoing major renovation, whose demand for hot water exceeds 0.8 MW per day, to meet at least 60 percent of their demand using solar thermal energy.
[45] The surface of solar thermal square meters in the city increased from 1.1 m^2 per 1,000 inhabitants in 2000 to 19 m^2 per 1,000 inhabitants in March 2005.

with the installations on the roofs of the *Ayuntamiento's* two main administrative buildings, *Nou* and *Novissim*, in central Barcelona. Since then, over 30 other PV installations have been placed across the 10 *distritos*, on community centers for the young and old, schools, and other public and civic buildings. The high profile 'Forum 2004' PV installation (see Section 6.3, Figure 6.4) is yet another artefact in the portfolio of a municipal leadership utopic. As explained in the factsheet of *PV Upscale*, a EU-level PV promotion initiative, the *Ajuntament* sis positioned as a potentially important player in stimulating the emergence of greener alternatives:

> "the promotion of PV by the municipal administration… to develop projects that can be used as a model for the private sector, thus creating confidence and stimulating the market."
> (PV Upscale 2005:3. **#B125**)

Understanding how a city, which in the early 1990s did not display significant environmental commitments in its urban development policy (Marshall 1993), has come to be celebrated as a "pioneer municipality supporting energy sustainability" (PV Upscale 2005. **#B125**) needs to take into account the municipality's growing importance in managing Barcelona's urban environment, more generally. Since the times of the Olympic Games in 1992, this is a theme that has featured in academic debates on urban regeneration. The notion of the 'Barcelona model', an example of urban regeneration to be followed, while questioned by critics, is thought to have been characterized by a '*modus operandi'* that put Barcelona 'on the map' (Acebillo 1999). The run-up to the Olympic Games (1986-1992) is unvaryingly identified as a turning point in Barcelona's recent past (Monclús 2003). One of the consequences has been the strategic promotion of specific economic sectors of the urban economy, one of which is 'new technologies'; such as PV, which if fully taken advantage of would make Barcelona one of the cities making "the most use of solar energy" (PMEB 2003). Instrumental in this process has been the setting up of the *Barcelona Energy Agency* (*AEB*, in 2002), as the entity charged with implementing the logistical side of the municipal energy improvement plan of 2003. The *AEB* has effectively acted as the operational arm for delivering the municipal PV projects. In the process of soaring to a 'high position in the international urban ranking' (Ajuntament de Barcelona 2003b), for instance, Barcelona was awarded the *EU DG Energy*'s '*ManagEnergy* Local Energy Action Award' for the *Ajuntament*'s 'commitment to sustainable energy solutions' (Manag'Energy. **#B114**) there was interaction only with non-national partners (ICLEI, PV Upscale, Energie-Cities; see Figure 4.20).

However, while fruitfully combining with state-level financial problem-solving techniques of the *Gobierno de Espana*, the *Ajuntament*'s leadership utopic was not readily compatible with the aspirations of other actors, notably the non-governmental organizations, *Fundación Tierra* and *Greenpeace*. While the latter was mostly pushing for more ambitious carbon reduction policy commitments, by renewable means (including PV) at national and regional levels, the former was overtly not aligned to the *Ajuntament*'s exclusive focus on municipal demonstration projects. Instead of using PV as a technology purely for achieving carbon reductions and international standing, the *Fundación*'s utopic of critique was aimed at the environmental implications of the entire socio-economic organization of the electricity sector in Spain. Attempting to turn clients into generators, the multi-investor *Ola Solar* on one of Barcelona's markets, the Guerilla solar and their own system, along with their various other initiatives; this group of people saw a much greater role for PV to be played in Barcelona (see also Section 6.4 'energy city') (Fundación Tierra 2007; **#B67**; Bosque Garcia and Domingo Marín 2008. **#B48**). While the municipality's purpose was served by the demonstration projects, projecting ambition and leadership to the outside, others' aspirations for eco-empowerment were held back by bottlenecks at the scale of the state, relating to the conditions for being rewarded the feed-in tariff (in more detail, Section 5.2.3). The absence of synergy between government financial problem-solving, municipal carbon reduction and non-governmental eco-empowerment aspirations emerged as a defining characteristic of the Barcelonan case as I found it in the Spring of 2009.

By the time I arrived in Barcelona, I was told, "there have been certain things going on here, a few years ago, but these have pretty much run out of steam" (Activist-Intellectual, Barcelona, March 2009). Nonetheless, while installations were far from mushrooming in the city, the 'PV Ordinance', was passed by the *Ajuntament* in 2010. This by-law, a mirror policy to the 'Solar Thermal Ordinance' makes mandatory an amount of PV on new buildings and renovation projects. While there is little doubt that this is a progressive policy, which was (eventually) achieved on the basis of genuine commitment, the rather 'tired' state of PV in Barcelona becomes evident when considering that the policy (as opposed to its speedier counterpart) spent 5 years in the pipeline, and its significance is drastically reduced by the fact that it is not thought to impact significantly in a city as dense as Barcelona, where new constructions and renovations are few. The question of existing buildings continues to be an ad hoc undertaking, with little suggesting that the rooftops of Barcelona's *Eixample*, or of any other Barcelonan district, will grow solar power plants in the near future (see Section 6.4). In parallel, the Spanish state's constant tinkering with the conditions of the national feed-in tariffs (see also Section 5.4) has had deleterious consequences on the national PV industry in general. At the time of research, the Solar Guerrilla panels were the latest initiative by *Fundación Tierra* to generate momentum behind an otherwise fractured technology.

In contrast to this Barcelonan experience, in London I arrived at a time when PV was relatively high on the agenda. This provided a rather different composite urban dynamic to the relative absence of synergy between actors in Barcelona.

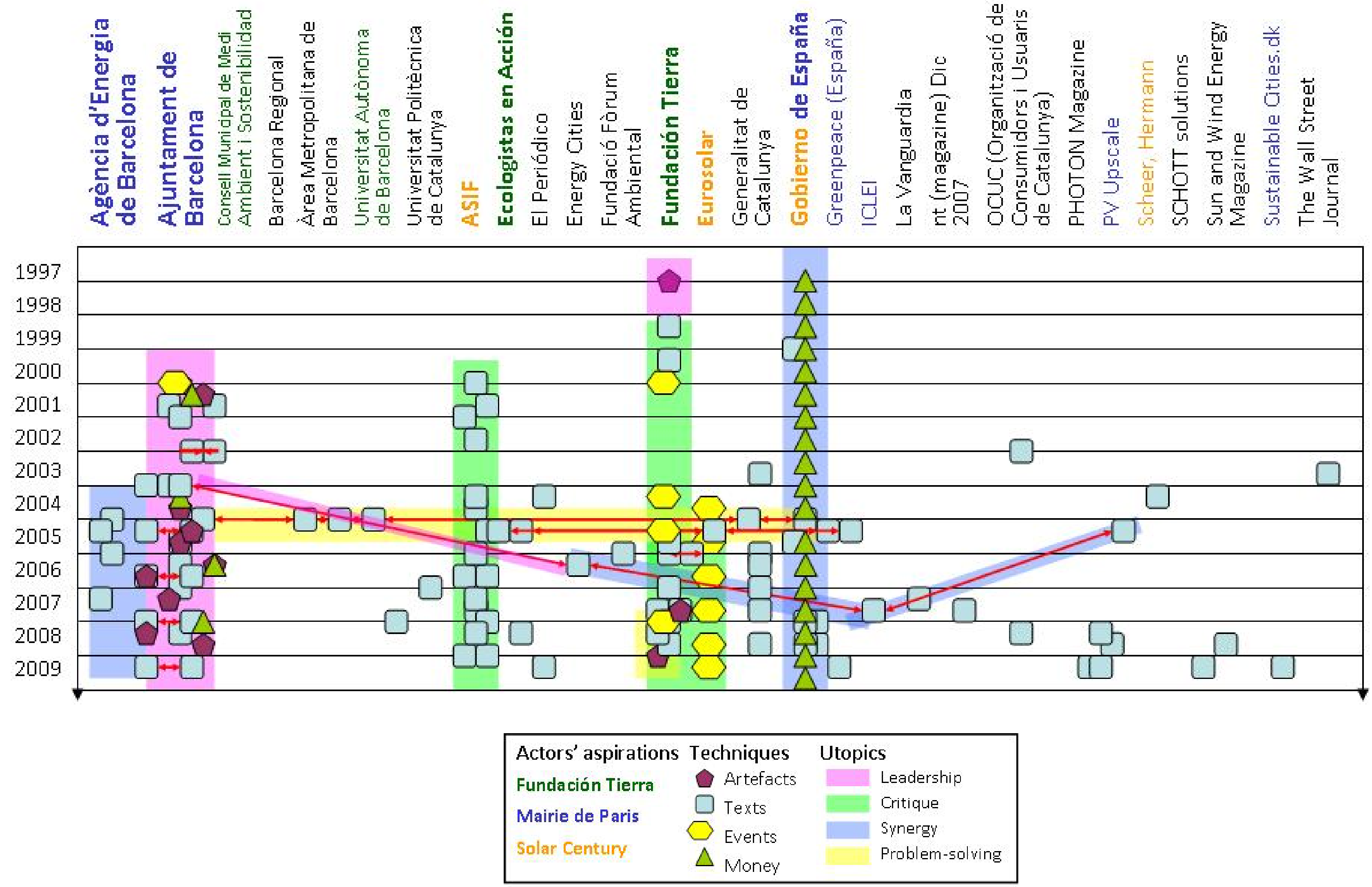


Figure 4.20 Urban PV: Barcelona

4.5.2 London

In London PV's emergence occurred rather later than in Barcelona, in the mid-2000s. This, occurred, however, analogously to Barcelona, at the government and state levels. Rather than feed-in tariffs, which would have constituted a commitment to PV as an legitimate electricity generator (for livelihoods, as in Spain), from 2000 onwards the UK government orchestrated a series of demonstration projects. The 'Domestic' and 'Large Scale' Field Trials, and the Major Demonstration programme constituted a rather tentative exploration of the technology's suitability for meeting government's carbon reduction aspirations, rather than an fully concerted effort to build a market. Following the consolidation of experience from these programmes (EST 2005. **#L45**; 2006. **#L46**), government initiated the 'Low Carbon Buildings Programme' (LCBP I+II), a more explicitly market-orientated grant support programmes which channelled one-off finance towards reducing end users' expenditure on the capital costs of systems (see Section 4.3.4). In this process, *Solarcentury* – as a 'framework provider' of the tender process – emerged as a key player, characterized by a livelihood aspiration to expand their UK solar business. The company's productive way of innovating includes its own enduring solar4schools project and its framework activities through which it funnelled government and private sector finance across a growing installer base at the lower end of the supply chain; thus effectively synergizing with downstream economic actors (such as other specialized installers, and the non-profits *Creative Environmental Networks* and *Carbon Descent* (former *SEA/RENUE*)).

In parallel, urban-scale politics of the early 2000s brought a new mayoral set up to London, led by a figure, Ken Livingstone, for whom brought PV was a technology for realizing 'low carbon' urban aspirations for London. Like the *Ajuntament* in Barcelona in 2003, in 2006 Livingstone set up an executive arm for his urban climate change and energy programme – the *London Climate Change Agency* (*LCCA*). The agency became the period's single most important deliverer of climate change projects in London; managing the delivery of, for instance the systems at City Hall and Palestra. As can be gleamed from Figure 4.21, the Mayoral leadership utopic of artefacts and text-based strategies for the following years distinguished itself from government's problem-solving cascades of financial architectures and national white papers and strategies. While the importance of financial architectures should not be downplayed, in the UK Government's energy policy as a whole, PV played a rather peripheral role. In contrast, Mayor Livingstone's Energy Strategy (2004), Climate Change Action Plan (2007) and London Plan (2008) targeted the installation of 80MW of PV capacity in the coming decade (an ambitious target considering the relatively low profile of the technology in London at the time. This, as stated in the London Plan, was thought to be delivered mostly by the private sector as part of new developments across the capital. However, the policy triad that Livingstone's term established was subsequently downplayed, following elections that brought a change of Mayor in 2008. In the period following Livingstone's office, the importance and desirability of meeting self-imposed emission targets and the delivery of previously encouraged PV projects on municipal building stock diminished. Amongst other developments, the new Mayor ordered the organizational incorporation of the *LCCA* into the existing regional strategic body, the *London Development Agency*, thus thoroughly reducing the agency's role in delivering a 'low carbon' capital.

By the time of research, the period of municipal 'flagship' demonstration projects in London had passed; however contrary to Barcelona, this has not practically halted the emergence of PV in London. While projects such as Palestra and City Hall have failed to constitute convincing examples of 'value for money' emission reductions (see Section 6.3), *Solarcentury* continues to synergize with the UK Government's financial architectures. In the process, a number of Londoner PV systems are being delivered, both through 'project' and 'product' contracts. At the national level, PV became increasingly seen as a potential avenue through which the UK Government could deliver the 'Renewable energy Strategy' (DECC 2009. **#L22**) and the 'Microgeneration Strategy' (BERR 2008. **#L5**). In these government strategies, PV has become a technology for delivering carbon reductions whose desirability is conditional. This is reflected, notably, in the newest UK policy, the 'GB feed-in tariff' (see Section 5.4.1) that came into force in 2010, which rewards a preferential rate to relatively small, building-integrated[46] PV systems rather than larger 'solar farms'. Governmental aspirations concerning PV, as a result, channel finance into bringing about PV in the built environment and under the ownership of entities that are not established energy utilities. However, while welcomed by the budding UK solar industry in principle, the latter did not align with the UK Government's exclusive focus on this particular market spectrum. Organisations such as the *REA/STA*, the *Micropower Council* and UK-PV, urged Government, through the publication of several statements, consultation responses, and studies generating an evidence

[46] Note that here 'building-integrated' refers not to BIPV artefacts (e.g. tiles, shading structures) but to systems in the built environment, including superimposed as well as 'building-integrated' PVs, strictly speaking.

base for their case, to reconsider their position on PV. Arguing for a greater role for solar, the *UK-PV Manufacturer's Association* (UK-PV 2009. **#203**), for instance, published a response to Government in which they argued that if all south-facing roofs and facades in the UK (approx. 1,100km^2) were covered with standard PV modules this would generate the equivalent of 26-35 % of total UK electricity consumption (in 2008; between 105-140 TWh (terawatt hours) of solar electricity – including east and west facing surfaces increases this figure to 374 TWh, and the potential for ground-mounted generation adds a further 346 TWh.

Misalignments between Government's and industry's aspirations for PV continue to characterize the situation of PV in the UK as well as London itself. On the whole, while the solar industry in the UK has historically been barely existent, through bodies such as the *REA*, the recently re-launched *STA, UK-PV*, and *Solarcentury*, a lobby for PV has emerged in the UK; with the result that installed capacity as well as employment in the industry continues to grow, despite somewhat inconsistent government policy signals. As in the case of Barcelona, livelihoods and carbon reduction have proved compatible with consequences that are only beginning to unfold. However, in London itself PV nowadays features relatively little as an instrument for achieving a 'low carbon' London. The leadership and problem-solving utopics of the Mayor and *LCCA*, respectively, that sought together to set 'exemplary' precedents and 'test' the delivery of PV in London, have given way to leadership change and shifting policy priorities. At the time of writing, it is the impending 2012 Olympics in London, and the associated debates about their financial costs, social benefits to Londoner's and, more broadly, London's role as world city, that have taken the centre stage. On the whole, Innovation in urban PV in London, evidence would suggest, is a matter that has largely shifted to debates between industry and government, in the form of contestations about the content and conditions surrounding the UK Government's financial architectures; and are dominated by a concern with the best way of support the emerging domestic (mostly downstream) industry.

As both the case of London and Barcelona suggest, upholding a separation between the strictly 'urban' and other spatial scales – the national, regional, sub-urban – becomes increasingly difficult as actors' entangle one another through techniques into their various utopics. And, emerging at the intersection of these, an 'urban' PV is enacted diffusely and in fragments, rather than as a coherent singular technology. The final urban context, Paris, is not different in this respect. However, as the following section explores, the Parisian case has neither 'run out of steam', nor has it yet ‘taken off’: rather it constituted a situation full of potential, however lacking evidence of significant developments.

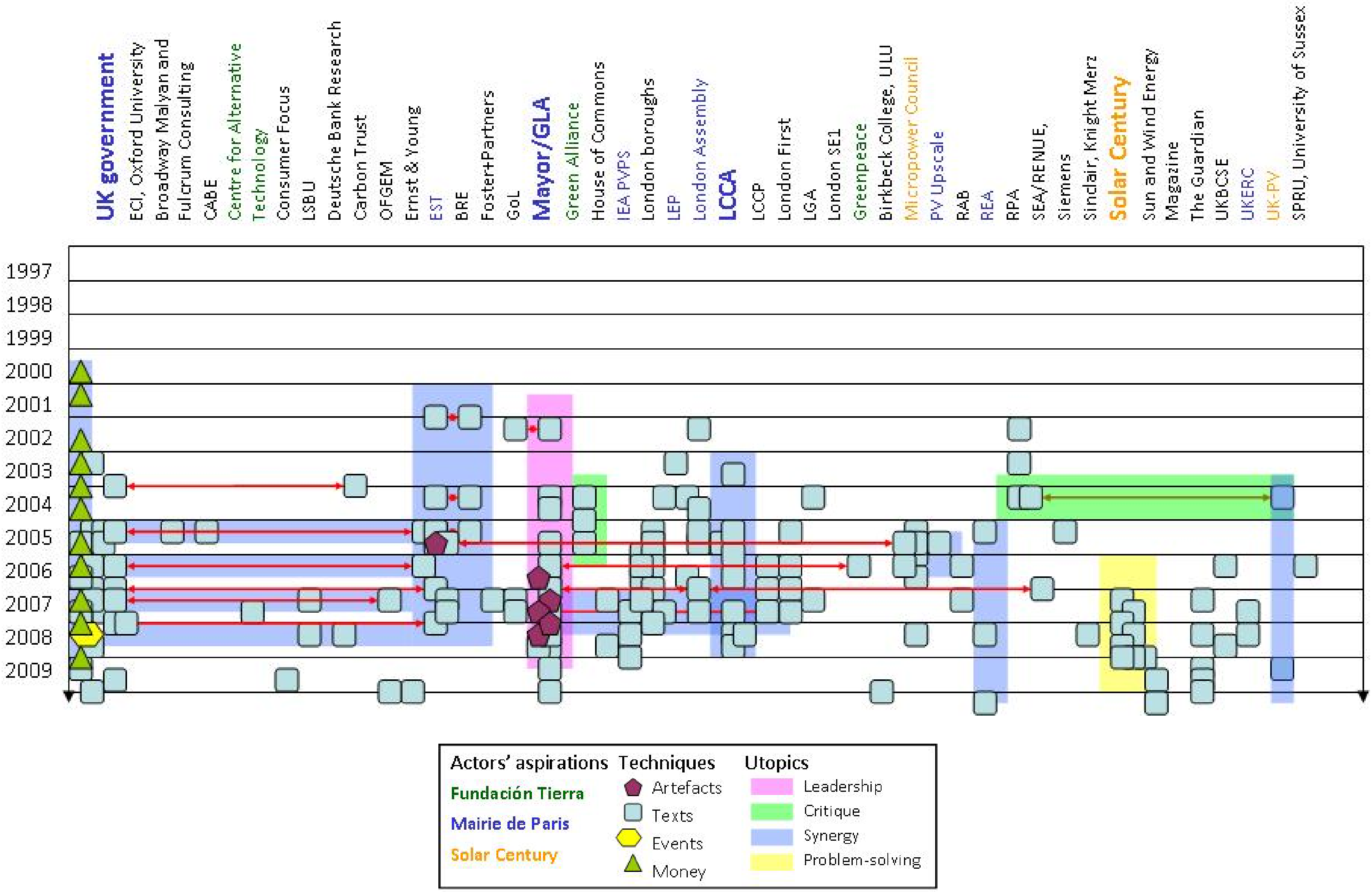


Figure 4.21 Urban PV: London

4.5.3 Paris

The early catalyst in the Parisian PV case was, as in Barcelona and London, the coming into force of the national government's financial architecture, the French feed-in tariff (*Tarif d'Achat*), in 2001. While prior PV had not been a legal possibility in its grid-connected form (see further Section 5.2.1), this effectively made it possible for environmentally driven organisations, such as *CLER*, to begin launching urban PV installations. Events at that time were thus marked by revival and legitimation from the state level, of the notion that PV was a simultaneously environmentally, socially and economically desirable technology. An energy agency interviewee explained that this was particularly meaningful in the context of France's predominantly nuclear energy system with its centralised set up, built around the 1970s' concern about energy security (see also Section 5.3.1):

> …without CLER at the start, today renewable energy would still be vegetating slowly. Because at the start – *CLER*'s been around since 1984 – when there was the 'counter' oil choc, a time when all that was being built was nuclear, while solar was being abandoned because oil was cheap again… and they said, 'no, we must continue. Just because the barrel of oil is cheap does not mean we can stop being thrifty and installing solar panels… (Energy Advisor 1, *IDEMU*, Interview, Paris, May 2009)

CLER were (and continue to be) an organisation with a "coherent stance on energy policy", who facilitate the cross- and trans-national exchange of experience and who, crucially, "publish a lot of things on PV [shows me on his computer], fact sheets, their regular newsletter *CLERinfo*" (Energy Advisor 1, *IDEMU*, Interview, Paris, May 2009). The organization's multi-faceted critique and problem-solving activities derive from an aspiration for eco-empowerment in which ownership of energy infrastructures would be decentralised to all, ultimately for a more benign form of resource consumption. While CLER continued to innovate through critique and problem-solving, government livelihood aspirations began to take shape, expressed in the introduction of changes in the feed-in tariffs in 2006. Specifically, preferential tariffs were introduced with the view of cultivating the development of a specialised domestic 'building-integrated' market niche. While the first feed-in tariff had made PV 'legal' (see section 5.4.1), the reform also explicitly encouraged the development of a domestic PV market. Domestic, both in the sense of promoting national supply *and* demand: fostering French industrial capacity as well as steering the manufacturing base towards producing a product that would cater for the peculiarity of the French market. Specifically, the French *Tarif d'Achat* was designed to stimulate the supply of a solar technology that resonates with the emphasis upon architectural aesthetics, which are typical of French laws on planning and 'urbanism'. While these frequently constitute important obstacles to those seeking to innovate (see notably Sections 5.3.2, 5.3.2 and 5.3.3), the emergence of a building-integrated industry, explicitly sensitive to the bespoke aesthetics of buildings, provided a favourable context for the emergence of PV in Paris itself.

PV installations on the Parisian territory, governed by its strict planning laws, stand in stark contrast to systems such as *CLER*'s own, which is aesthetically speaking "nothing special" in the context of their equally "rather bland surroundings"[47] (Director, *CLER*, Interview, Paris, May 2009). While PV is enacted as a technology suitable for achieving local aspirations of carbon reductions, in Paris this is generally conditional upon its aesthetical integration into the Parisian cityscape (see 5.3.3). The notion of aestethics is a theme that thoroughly pervades a Parisian account of PV. For instance, the contrast between *CLER*'s early pioneer system and later Mayoral initiatives (the 'hyper-protected' Carreaux du Temple, the high profile ZAC Pajol and the Eco-ZAC Clichy-Batignolles) is illustrative of the importance of a territorially bound imaginary of aesthetics that is codified in the law. The *arrondissements* of Paris, in contrast to suburban Montreuil (where *CLER* are based), are subject to strict development guidelines which are thought by some to stifle the city's ability to evolve with the times (see Section 5.3.3). In this context, government financial architectures effectively fostered the industry supply and demand of acceptable artefacts, while at the downstream, project delivery, end of the supply chain, non-profit energy agencies were being strategically set up by the national energy agency, *ADEME*, across the whole of France.

In Paris, these *Espaces Info Energie* (*EIE*), in turn, feature prominently in Mayoral initiatives, such as 'Copropriétés Objectif Climat' (*COC*), as problem solvers. The close relationship between the *EIE* 'instrument' and Mayoral ambitions is illustrated, for instance, by the fact that one *EIE* employee has a permanent office in the 'Citizen's Contact Point' in the Mayor's Office planning

[47] *CLER*'s installation is located on the rooftop of the organisation's headquarters in the Parisian suburb of Montreuil, which is relatively poor in sites of national architectural heritage.

department[48]. As a result of parallel state and municipal utopics, a more concrete urban PV dynamic was beginning to emerge in late 2009. The combination of experimental initiatives such as the *COC*, big strategic projects in the capital, the mayoral leadership rhetoric of the 'solar capital', carbon audits, the *Plan Climat* and the reform of city-scale spatial planning (see section 5.4.1), effected the loosening and decentralisation of procedures affecting the built environment in Paris. Despite the curtailment over recent years of governmental finance, evidence suggests that an urban PV is taking shape in Paris, which is characterised by novel forms of socio-economic organisation. The Parisian *SOLARVIP*, for instance, a public-private Energy Services Company, constitutes a potential seminal evolution in the way PV is managed in 'the city' in general (see Section 6.5).

The emergence of new patterns of relations, such as solar ESCos, and also 'rent-a-roof' schemes, is generally a development of which elements were also present in the Barcelonan and Londoner context. However, perhaps owing to the timing of the research, this unfolding transformation was most acutely traced in Paris. In all three cases PV is materially and discursively implicated in the continuous questioning of the future ecological, social, economic and political organisation of national and urban energy systems. In Paris, nation wide debates about the role of solar at the local and national levels persist, while locally efforts to make compatible aspirations for carbon reduction with the urbanistic demands of the city are taking place. In London, the future of PV has came to hinge upon its ability to provide 'value for money' carbon reductions, an issue which remains topical at the time of writing; however this is largely a national debate, which is sidelined in urban debates about the imminent Olympic Games. Similarly, in Barcelona, it would seem that the topic of solar energy for carbon reductions and international standing has been largely, and at least momentarily, overtaken by the growing economic crisis of the Spanish state, debt and unemployment.

However, as Chapter 6 will explore in detail, this is not tantamount to saying that PV has not had significant impacts in the cities of Barcelona, London and Paris. While there is little that suggests the 'accumulation' of urban PV 'niches' into their own regime, it will emerge that in a relational sense, PV is implicated in reworking urban social and material spatialities; thus generating transformations that are more subtle than an imaginary of niches and regimes allows to portray.

[48] *Pôle Accueil et Service a l'Usager, Direction de l'Urbanisme.*

While solar transformations are explored in Chapter 6, the following chapter will explore the contradictions, or ‘barriers’, that innovation in urban PV throws up in Paris, London and Barcelona. Specifically, Chapter 5 explores the various ways in which desires for change come up against the limits of what change is possible in the context of existing relations. It is important to note that the materials of utopics are very different depending on whether local energy agencies involve citizens through project-based initiatives, such as the ‘Copropriétés Objectif Climat’ in Paris, or consultancies such as *Barcelona Regional* and *Solarbuzz* who monitor and forecast through publishing strategic documents and market analyses. One may yield actual PV installations (if a project succeeds) and the other, weekly internet-based newsletters and industry reports that can be purchased for prices ‘beyond my research budget’. Thus, while both are effectively geared towards promoting PV, there are substantial differences in effect between the ‘leg work’ of carbon reduction and more strategic problem-solving utopics for livelihoods. This begins to draw into focus the way in which different ways of spatialising aspirations about PV may have very different spatial and material implications in practice.

Importantly, while one actor may be performing more than one utopic, this does not mean that different actors’ utopics will be necessarily compatible. The relationship between different actors’ utopics in terms of how well they convert ‘sustainable’ aspirations into reality is the theme of Chapter 6. At present, however, the chapter concludes with a discussion of the emergence in urban PV in Barcelona, London and Paris, respectively. The following section uses insights from the previous sections to provide a material semiotic perspective on each city’s PV scene. It does so by weaving the relationship between different actors’ utopics over time into three separate accounts of a ‘Barcelonan’, ‘Londoner’ and ‘Parisian' reality of urban PV. As it emerges, parallel realities of an ‘urban PV’ are beginning to consolidate, through actors gathering techniques into utopics for converting their diverse aspirations into reality – *within* as well as *across* cities.

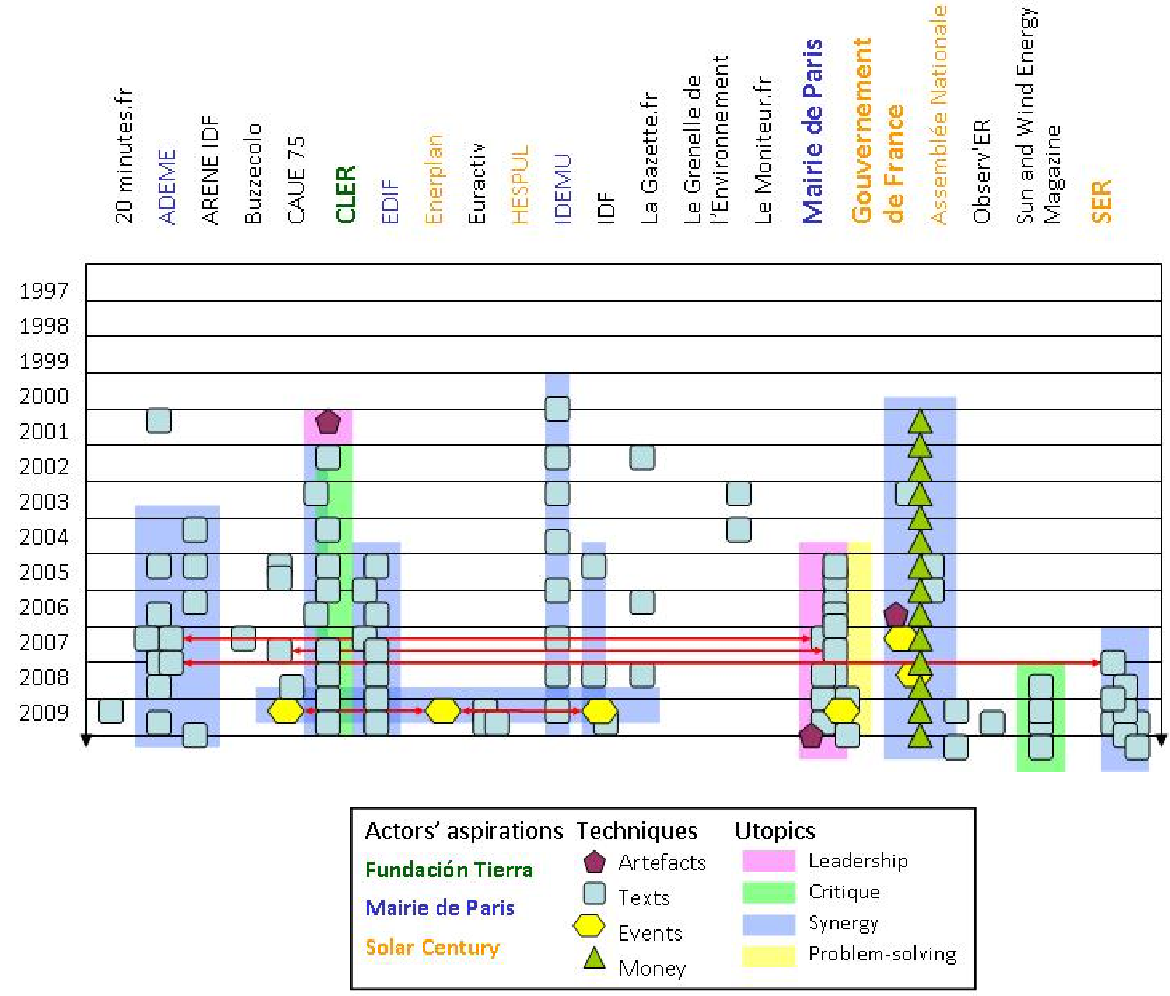


Figure 4.22 Urban PV: Paris

4.6 Conclusion

To conclude, this chapter was concerned with understanding the ‘urbanisation’ of photovoltaic technology: how PV is brought not only from ‘space to earth’ (Perlin 2000) but also to the city (see Chapter 1). The chapter began with the *IEA*’s definition of urban PV. this can now, based on the development of the concepts of utopics and utopical techniques of urban PV over the course of the chapter, be framed as an international group of technical experts which are enacting a problem-solving utopic that aims to foster the uptake of PV in cities through generating knowledge-based solutions from which others may implement solar electric solutions in the city. However, the *IEA*’s ‘urban PV’ is but one of many potential realities of urban PV technology. Wary of my own performative effect through a pre-given ‘urban’ research focus (see Chapter 3) the chapter argued that the intelligibility of an ‘urban PV’ technology is beginning to take shape which is at best partially coherent. Predominantly, PV in Barcelona, London and Paris did not in fact emerge as an expressedly ‘urban’ technology at all. Instead, it is at the intersection of aspirations for eco-empowerment, carbon reductions and livelihoods that an urban PV has become enacted in the context of this thesis. These, brought to life thorugh an strategic amalgamation of utopical techniques into utopics, have enabled a material semiotic accopunt of an elusive, complex technology that is multiple within *and* across urban contexts. Tracing particular relationships, it should be remembered, is a research strategy that does not strive for representativeness; instead generating a situated account in which the researcher recognizes her part in enacting a particular technological reality.

Taking into account this acknowledgment, the overarching argument this chapter presented is that ‘urban PV’ is both an outcome of as well as a vehicle for innovation: it exists in and through the conversion of actors’ aspirations into reality. Early on it was argued that for different actors PV is a technology that promises different futures. However, while aspirations may differ, as actors attempt to convert these into actual states of affairs, a set of utopical techniques become intelligible which are cast as constituting urban PVs heterogeneous common architecture. Utopical techniques, through mediating social, material, spatial and temporal relationships, are *the very relations* through which urban PVs’ various realities are enacted. Utopical techniques acquire their relational significance as such in utopics which are the practices through which actors seek to ‘make a difference’. The relationship between the chapter’s key themes – solar aspirations, utopical techniques and utopics – is summarised in Table 4-3.

A diversity of actors introduced over the course of the chapter aspires for ‘solar cities’, broadly speaking, for a range of reasons and act upon their visions through different means. A range of non-governmental organisations aspire to a state of eco-empowerment of citizens and other non-traditional electricity generators through changing the ecological and socio-economic organisation of electricity systems. They translate this desire into reality by blending leadership, critique, synergy and problem solving utopics through their PV installations, participatory projects, rhetorical manifesto statements, celebratory prize-givings; advocating alternatives solutions (such as the guerrilla panel campaign) and range of subversive literatures; seek synergies of financial character across the sectors and identify solar electricity solutions for individual cases and entire regional and national territories. While central to their PV version of eco-empowerment is the involvement of civil society in the means of power generation, another set of (mostly governmental) actors have a rather more narrow definition of the utopical value of PV, in terms of reducing the externalities of existing powering infrastructures. These actors rarely transgress, perhaps owing to the fact they are themselves ‘the powerful’. Instead they lead by orchestrating demonstration and flagship showcases, make public their support for change through official strategies, setting of targets; they channel funds into synergising with financially well-resourced corporate actors and citizens; and provide the technical knowledge which frame domains for intervention. Yet another set of (mostly commercial) actors PV is a means for sustaining livelihoods in terms of generating income, profit and expanding their businesses. To make people “sign on the dotted line” (Project manager, *Solarcentury*, Interview, London, November 2008) commercial actors will critique existing frameworks (often through formal channels of consultations), and forge synergies through a range of events and partnerships with a range of – governmental, corporate and civil society – actors; including assisting these with the delivery of projects.

On the whole, a material semiotic analysis of urban PV such as presented in this chapter is attuned to grasping how innovation entangles a diversity of actors, spaces and materials; and their agendas, histories and debates. The value of understanding urban PV not as a technology that is singular in purpose, is that scope is created for understanding that a multiplicity of engagements with ‘the same’ technology (i.e. ‘interpretative flexibility’ – see Chapter 2.5.1) have very material consequences. This enables a more intricate analysis than made possible by more established innovation studies approaches. In the latter, technology is rarely interrogated, but rather assumed to take on particular material forms (i.e. the artefact) and social meanings (in the case of renewables energy technologies, such as PV, that they are ‘green’ or ‘sustainable’). As a result, approaches such as *SNM*/*MLP* have tended to downplay the diversity of actors, the various roles of technologies and different modes of innovating. In contrast, the material semiotics of urban PV developed in this chapter constitutes a nuanced and layered understanding of what it is about technologies such as PV that makes them attractive, versatile and potentially effective means for bringing about a diversity of aspired-to future outcomes. Crucially, the *SNM*/*MLP*’s assumption that as expectations about technology ‘converge’ over time, niches will ‘grow’ and ‘stabilise’ (see Section 2.2.3) is problematic as visions of carbon control, business expansion and far-reaching social change are based on fundamentally different notions of what is ‘technological’. It may be the case that that potentially numerous parallel and competing ‘versions’ of PV co-exist alongside one another, even within the same city.

Whether ‘expectations’ – or rather, sociomaterial realities – converge or not, evidence would suggest that there are complementarities and commensurabilities in the utopical sense of being concerned with making material differences to the prevailing ‘conditions of possibility’ (see 2.5.4). However, utopics, as explored in this chapter, constitute *attempts* to innovate. As Chapter 2 (Section 2.5.3 specifically) noted, efforts to innovate are fraught with difficulties as innovation does not take place in a vacuum. Just as utopics evolve over time, as this chapter explored, this is accompanied by changes in the conditions of possibility. Continuing the inquiriy into innovation in urban PV, the following chapter is particularly concerned with the challenges of bringing about new technological possibilities. Captured through the notion of ‘regimes’, the following chapter asks about the heterogeneity, spatiality and temporality of those pre-existing relations that become meaningful obstacles to those seeking to innovate.

Table 4-3 Urban photovoltaics as an effect of utopical techniques at the intersection of aspirations and utopics

Urban photovoltaics			
	Eco-empowerment	**Carbon reduction**	**Livelihoods**
Aspirations	Reconfiguring ecological and socio-economics of electricity generation	Governing the reduction of GHG emissions of electricity generation	Income and profit, business expansion through costumer and policy support for
Actors	Non-governmental advocates	Municipal and national actors	Commercial actors
Utopics			
Leadership	Own systems, participatory projects, <u>manifestos</u>, *prize-giving*	Demonstration and flagship showcases, <u>strategic documents, targets</u>	
Critique	FT's SG panels, <u>CLER's grey paper, Flyers, websites</u>, *Campaigns*		<u>Consultation responses</u>
Synergy	FT'SG andl CLER's own systems, Solar guerrilla panel, **Sponsorship**, **charitable funding**	**Outsourcing framework contracts, feed-in tariffs, grants, tax breaks**	*Networking/promotional events* ,<u>CSR projects</u>, **CSR sponsorship, government contracts**
Problem solving	Project assistance, <u>Greenpeace's report, Catalunya Solar</u>	<u>Reports, benchmarking studies</u>, *audits*	Project assistance
(Legend: artefacts, <u>texts</u>, *events*, **finance)**			

5 Barriers 'in action': heterogeneity, spatiality and temporality

5.1 Introduction

In a very basic way, innovation is a challenge. In the absence of difficulties there would be no place for the utopics of innovation that the previous chapter explored – leadership, critique, synergy and problem-solving. However crucially, utopics are *attempts* to spatialise novelty. Understanding the challenges facing those seeking to innovate is the aim of this chapter. The importance of doing so derives from the importance of what in policy and academic literatures have been referred to as 'barriers' to implementing new technologies (Guy and Shove 2000; Shove 1998; Bulkeley et al. 2005; Guy and Marvin 1996). Here it is not the intention to reify the somewhat problematic imaginary implied by a 'barriers' discourse – as deterministic absolute, homogeneous and timeless – obstacles, which must be 'overcome' and 'leapt' (Hobson 2003; Bulkeley et al. 2005; Guy and Marvin 1996; Hobson 2006). Rightfully, Bulkeley et al. (2005: 1) argue that a 'barriers' discourse perpetuates "an unhelpful division between the 'technical' and the 'social', and between policymaking and practice". This is an important criticism in light of this thesis' material semiotic position which is cautious of both the use of 'hard' categories that risk essentialising and the strict separation of practices such as 'policymaking' and 'practical implementation'. However, the chapter avoids a full-out rejection of the notion of barriers (as Bulkeley et al. suggest) in favour of interrogating how it is that that which is already 'in place' (i.e. regimes) may be experienced as barriers for making material that which could be (and, according to innovators *should* be).

The chapter builds on innovation studies literatures' understanding of innovation as an interplay between novelty and normalcy, however comes to a rather different interpretation of what this means for analysis. In *SNM*/*MLP* it is thought that 'socio-technical regimes' are *networks* of actors, rules and artefacts (Geels 2004; Schot and Geels 2008) that 'lock out' new technologies from existing socio-technical systems (for example, the 'energy system'). While there is merit in the ambition to theorise that which predates innovation, Section 2.5.4 argued that the *SNM*/*MLP*'s notion of socio-technical regimes risks veering towards essentialist description by projecting onto the object of analysis a predetermined set of assumptions. The argument, made in the abstract in

Chapter 2, was that greater analytical sensitivity is required than a vocabulary of ‘lock out’ and ‘networks’ allows for, in order to produce a deeper interrogation of the character of novelty and normalcy as situated phenomena that are constituted relationally to one another in boundary-making practices – utopics. This chapter makes concrete the implications of material semiotics for understanding the quality, texture and dynamic of that which predates efforts to innovate. While retaining a general vocabulary of ‘regimes’, the chapter works through generating a range of metaphors through which regimes can be analysed. This is made possible by engaging material semiotic sensibilities with a variety of existing compatible literatures (in particular those used by urban and political geographers). The use of ‘metaphor’ suggests an analytical rather than an ontological argument – in other words, metaphors are used over the course of this chapter not to make claims about the nature of reality but rather as analytical devices in the sense in which geographer Howitt (1998: 49-50) uses the notion, as a means by which one can “establish, clarify and analyse connections, comparisons and meaning… to unsettle the dominant binaries and master narratives”.

The chapter argues that an analysis of the challenges to innovation must be attentive to the diverse ways in which existing relations impact upon efforts to innovate (*heterogeneity*), to the range of relational constellations that generate such effects (*spatialities*) and to the ongoing reconfigurations of the prospects for innovation (*temporalities*). In the first instance, Section 5.2 develops an account of ‘barriers *to* action’ as encountered ‘*in* action’. This seemingly subtle analytical shift implies exploring barriers in terms of the qualitatively heterogeneous ways in which they are encountered by different actors as they innovate. Casting barriers as ‘regime effects’ that are intelligible ‘in action’ enables a layered account of how barriers are very real and formative aspects of actors’ experience of innovation in practice. Following this argument about the heterogeneity of barriers to innovation, Section 5.3 inquires into the relations that produce such barriers. Here it is argued that regimes are the relations that predate efforts to innovate (as in *SNM*/*MLP*), however, that they can be usefully understood as consisting of a range of spatial forms. Rather than singular in shape and spatially homogeneous, a range of metaphors is generated to talk about different textures of regime spatialities; inclusive of, however transcending, *SNM*/*MLP*’s imaginary of territorially congruent networks of actors. Section 5.5 brings to the fore questions concerning the temporality of regimes (which remains a rather implicit feature in the *SNM*/*MLP* framework). This brings with it an argument that the prospects for innovation in urban PV can be understood as taking shape through four interrelated temporal imaginaries, which capture how the conditions of solar possibility change.

5.2 Heterogeneity of 'lock out'

This section broadly concurs with Bulkeley et al. (2005) – that barriers should not be reified as essential features – a material semiotic account also suggests that if 'barriers' constitute the frame of reference through which actors themselves understand their innovative practices, then taking seriously the imaginary implied by barriers is important. For instance, along with a range of actors, the regional Catalan authority suggests that *barreras* to innovation in PV are of 'regulatory', 'economic' or 'social' character (Generalitat de Catalunya 2006). While this implies for the Generalitat that regulatory reform, financial support schemes and awareness raising activities are key interventions for fostering PV, the use of 'hard' categories for capturing barriers risks obscuring their interconnection (Hughes 1986). In what follows a rather different understanding of barriers to that which prevails in scholarship, policy and practice is put forward. This section engages with the prevailing (*SNM*/*MLP*) understanding of socio-technical regimes as leading to the 'lock out' of technologies such as PV. However, it is argued that it is not sufficient to state *that* regimes 'lock-out' new technologies through path-dependent 'rule systems' (e.g. Kemp et al. 1998; Del Rio and Unruh 2007; Geels 2004). Such a portrayal gives little indication about how this 'lock out' is experienced – and thus, what relations produce it (Section 5.3) and what the prospects are for resolving it (Section 5.4).

Specifically, barriers are cast as constituting the challenges experienced 'in action' by those innovating across their various utopical interventions – as they lead by example, offer up alternatives through critique, seek to forge synergies across diversity of interests and identify problems for enabling others to act (see Section 4.4). These utopics were understood in Chapter 2 (Section 2.5.3) as boundary-making practices in which the distinction between 'novelty' and 'normalcy' becomes intelligible. While the previous chapter's exploration of utopics suggested that what it means to innovate through PV is multiple in practice, here this insight is extended to an argument that there is not a singular reality of how barriers are experienced across diverse utopics. Instead, by attending to the effects of regimes 'in action' the section distinguishes between four main ways in which challenges to innovation are experienced: *exclusion*, *subordination*, *obstruction*, and *disconnection*. These different terms should not be understood as necessarily exhaustive ways of capturing barriers to innovation, but they were the metaphors that aptly capture barriers to PV in Barcelona, London and Paris. These are used to abstract from the 'messy' world of innovation (Beveridge and Guy 2005) a set of qualitatively different experiences of regimes in action. Like utopics, which are carried out by different actors in a diversity of ways (see Section 4.4) barriers – which exclude, subordinate, obstruct and disconnect –are not mutually exclusive, as Section 5.3 will explore. The merit from such a material semiotics of barriers is that it avoids generating a potentially endless list of elements that comprises 'lock out' in favour of a qualitative engagement with actors on the ground encounters.

5.2.1 Exclusion

The notion, prevalent in the innovation studies literature, is that renewable energy technologies are 'locked out' from existing energy systems (Kemp 1994; Unruh 2000;Del Rio and Unruh 2007) is a useful starting point for describing the challenges encountered by a set of 'pioneering' actors seeking to deliver small-scale PV systems; *Comité de Liaison Energies Renouvelables* (*CLER*) and *Fundación Tierra*, in Paris and Barcelona, through their critique-based activities to promote PV and upon seeking grid connection for their small terrace PV system. According to its director, for a long time *CLER* promoted PV as a technology suitable for 'off-grid' sites beyond the reach of transmission lines, in particular in the lesser electrified pacific and Caribbean DOM-TOMs (overseas 'departments' and 'territories'). During an interview he explained that PV could not be envisaged as a grid-connected technology as it was simply illegal:

> Back then[49] it was actually prohibited to connect to the grid. So simply connecting to the grid wasn't possible… and back then we were saying it ourselves: 'PV is for remote applications'. Never would you even see it [grid-connected PV] mentioned in an official communication.
> (Director, *CLER*, Interview, Paris, May 2009)

The exclusion that PV faced in *CLER*'s experience was a complete disarticulation in the sense that even actors generally or actively in favour of the technology, such as *CLER* themselves did not conceive of the possibility of grid-connection. For the interviewee this was intimately tied to the

[49] Before introduction of the national feed-in tariff in 2001.

fact that electricity operated according "to a centralized production and distribution logic, and decentralized, that just wasn't the logic at all in France". He related the formal illegality of PV (and other non-centralised grid-connected generators) as intimately related to the prevailing "all-electric, all-nuclear" state-endorsed electricity infrastructure ideology (Hadjilambrinos 2000). This performed centralised power as the 'normal' and optimal way electricity should be organised and effectively excluded PV from mattering, materially and discursively. While it would apt to say that PV was 'mismatched' to established "rules, principles and practices" (Verbong et al. 2008: 569) this risks masking the nuances of exclusionary effects.

While *CLER*'s experience constitutes a degree of total exclusion from mattering, a different case from this total disarticulation of non-centralised grid-connected electricity generation is illustrated by the experience of *Fundación Tierra* in Barcelona. In 1998, the organisation sought to connect their small scale 2,2 kilowatt peak terrace-shading system to the electricity grid in the context of the entry into force of Spain's first feed-in tariff and their own organisational activist philosophy (see Sections 4.2.1 and 4.4.2). While the feed-in tariff (*Real Decreto*) secured the formal legality of connecting PV to the grid, the *Fundación's* experience was that the 'dominant attitude' (i.e. by the Spanish government) of the time was that "a household is not a power plant" (http://www.ftierra.org/). As stated by the President of the *Fundación*, rather than illegality per se, the issue around which exclusion played out concerned the novel *scale* of power generation:

> back then it was not envisaged by the regulation that [small-scale] connections in monophasic [current][50] would be made, but only in triphasic. But not in any household you will find triphasic. And neither in an office, obviously. That's for industry and engines. (President of *Fundación Tierra*, Interview, Barcelona, March 2009)

It was not anticipated by the *Real Decreto* that small scale grid connections would be made as powering was implicitly thought to be a large scale matter (and indeed, the dominant type of PV in Spain to this day remains that of the large-scale (and non-urban) 'solar farm'). In the presence of

[50] This refers to different ways in which power is transformed as it is transmitted over distance using transmission lines. Here the use of 'monophasic' and 'triphasic' indicates different grid set ups, where monophasic is used by the interviewee to talk about 'local' grids to which domestic/urban users are connected and triphasic current which is the resolutions used in Spain to connect to industrial scale costumers.

this bias implicit to the *Real Decreto*, the Fundacion has been vocal about the exclusion of small-scale solar power from the electricity grid (see Section 4.4.2).

The experiences of *CLER* and *Fundación Tierra* illustrate that technologies such as PV may be 'locked-out', that is excluded from becoming material as well as discursive possibilities; however, rather than assuming that it will be the same everywhere the comparison of these two cases opens up the possibility for interrogating the qualitatively different ways lock-out is experienced by innovators: 'illegality' (in the case of *CLER*) and 'scalar marginalisation' (in the case of *Fundación Tierra*) both work to exclude PV, albeit somewhat differently. In both cases exclusion works through the creation of 'boundaries' as political geographers might use the term; in the sense of "'distinction' and 'separation'" (Painter 2006: 8). Delineating an 'inside' from an 'outside' (Law 2000b), understood as the capacity for drawing boundaries, does not refer here to the literal cartographic act of superimposing lines onto a map. Besides the literal, in political geography, boundaries are tied up with power relations – for instance, for Paasi (Paasi 1996: 17) the inside of the boundary is "an area controlled by a certain kind of power". Thus, making boundaries is to exercise power, for instance, through defining particular 'conditions of possibility' for the inside (Foucault 1986). The notion of boundaries is useful for developing a deeper understanding of how exclusion works in practice. For instance, while in *CLER*'s case PV is exclusion is absolute, as illegality upholds an impermeable boundary, *Fundación Tierra*'s experience is better understood as a boundary that takes the shape of a threshold (in this case of power output magnitude) below which PV is excluded. These examples draw attention to how exclusion may take rather different forms and be felt to different degrees.

Importantly, while exclusion works through defining an inside from an outside, or the creation of boundaries and thresholds, the following section turns to a different kind of regime effect that is experienced as barrier in action: that of subordination, by which efforts to promote PV encounter the technology as hierarchically subordinated to other relations.

5.2.2 Subordination

> …if the first doll is bigger than the second one and the second doll is bigger than the third, then the first doll is also bigger than the third. Which is, I agree, pretty obvious when applied to Russian dolls.
> (Law 2000b: 144)

To understand how another set of innovators encounter the barriers to PV differently than *CLER* and *Fundación Tierra* it is helpful to draw on the mathematical metaphor of 'transitivity' explored by John Law (2000). As the example of Russian dolls illustrates, transitivity refers to a distribution of relations according to which some elements are larger, or more important, than others. As Law illustrates, transitivities are not unrelated to boundaries, as the very existence of transitive relations largely relies on boundaries (e.g. between differently sized dolls) to exist in the first place. However, when applied to innovation, the effect of transitivities signals a different type of regime effect than that of exclusion. As opposed to working through exclusionary boundaries and thresholds, transitivity suggests that relations of hierarchy may exist between different entities, or entire domains of activity, which effect to subordinate one to another. Here efforts to implement PV may face challenges in terms of the precedence that other relations take over the technology. Two examples from London and Paris serve illustrate this subordination of PV to urban priorities, associated with 'economics' and 'architectural heritage', respectively.

The case of London exemplifies how PV's environmental credentials – of generating the sorts of 'low carbon' electricity that is seen as desirable in the city (GLA 2004; GLA 2007; GLA 2008) – are more often than not subordinated to economic cost calculations when it comes to actually installing PV systems. The following extract from an interview with two London-based architects illustrates how their efforts to promote PV in their dealings with clients often fail:

> Interviewee 1: …that's one of the things we come up against as architects, we make proposals, green ideas, nothing dramatic. But these projects always go through cost dilemmas and… things that are bolt on, like PVs are going to be the things that get lost along the way [pauses]

> Interviewee 2: [jumps in] We try our best! And, then the contractor comes along [sighs]… They've persuaded the client, the client doesn't want to spend the extra money, bladi bladi blah… we'd like to see PVs, but it's very frustrating because we often feel like we are banging our heads against a brick wall… then you end up with a biomass boiler and standard insulation.
> (Architect 1 and Architect 2, *Jestico Whiles*, Interview, London, November 2008)

A range of transitivities are at play which effect to subordinate PV to other priorities. There are costs, for instance, a fact that effected frustration in both interviewees, as despite having the skills to specify PV and PV being much more suited to an urban building than, for instance biomass boilers (on air quality grounds). In the end, the decision is not theirs to make, but in the hands of 'the client'. A London-based engineering consultant qualified that "there's different types of clients"; however that most commonly clients "want to be quote green, which often means to know the best way of complying with 'part L' of the building regulation" (Architect 1, *Jestico Whiles*, Interview, London, November 2008). A second transitivity is thus introduced between clients potentially wanting to be 'green' but also having to meet building regulations which specify that a certain amount of renewable energy should be generated on the development site itself (as in the case of the London 'onsite generation policy (see Section 6.3). In fact, a number of technical studies have been conducted in order to assess how to convert building regulations ('part L' of the national building code but also local and metropolitan planning policies) and carbon emission reduction targets more generally into reality. For instance, the *GLA*-commissioned Carbon Scenario report (SEA/RENUE 2006) modelled that a renewable-led scenario (including large PV uptake) would produce similar emissions reductions to a micro-CHP led solution (10,414 ktpa and 10, 285 respectively), however involving almost double the capital expenditure (£ 14,591m compared to £ 7,455m). Even compared to other renewable technologies, such as urban wind for example, the Siemens Urban Infrastructures (Siemens 2008) report stated that PV's cost per unit of carbon abated as 20 times more expensive (costs of over "€1,000 per tonne of CO2 abated" compared to "abatement cost of €50 per tonne of CO2" for micro wind). Invariably, these studies argue that compared to other technological options, PV is an expensive (even *the* most expensive) choice.

A second example illustrates that a transitivity may be performed that subordinates the technology to other priorities on aesthetical grounds; as in the case of architectural heritage in Paris. This stands in stark contrast to how the technology's shiny (predominantly blue or black) exterior is frequently what makes it a glittering symbol for a diversity of actors' commitments to climate protection (Mairie de Paris 2006a; GLA 2007), ethical procurement (the *Cooperative*), eco-preneurship (*Solarcentury*) and eco-ethical consumption (*Fundación Tierra*). For the Director of *CLER* there is a real contradiction in the way that in Paris "one will say that PV installations must be visible to everyone, while the other will say 'PV ought not to be seen'… there is a conflict between having to hide and wanting to show". Most notably, the Parisian Mayor, Bertrand Delanoë, finds his ambition to promote PV in Paris (as the 'solar capital' (Delanoë 2007) caught in a transitive relationship between 'sustainable development' and the aesthetical demands of commitments to preserving the city's architectural heritage. The stakes of architectural heritage, termed *patrimoine*, need to be understood in the context of the notion, that "Paris' roofs are part of Paris' *patrimoine*" (Mairie de Paris 2006b), as stated in the preamble of the local spatial development plan. The guidance leaflet on solar PV installations published by the Mayor's office, as part of its aspirations to install a large amount of solar panels in Paris (see Section 4.4.1) frames PV as a 'fully-fledged' architectural element that has to conform to a very particular notion of aesthetics:

> In a city renowned for the quality and harmony of its urban landscape, installing rooftop solar panels exceeds pure energetic considerations. It's a matter also of respecting Paris' identity… solar panels must be considered as fully-fledged architectural elements which must be integrated on buildings in a manner that is harmonious with the existing cityscape.
> (Mairie de Paris (2010) *Installation de panneaux solaires*. #P84)

On the surface PV blends relatively 'harmoniously' with Paris' homogeneous dark grey and blue zinc rooftop landscape – compared to, for instance, 'red roofed' French cities such as Lyon – however, as will be further explored in the following in Section 5.2.3, in Paris, the meaning of 'harmonious integration' exceeds questions of colour. As a result, the Mayoral aspirations find themselves caught in a trade-off between urban environmentalism and architectural aesthetic requirements of *patrimoine*. In the following extract from a Q&A session at a private-sector organised event for public sector actors, the 'Conférence des Maires et élus pour le solaire', the

Green Deputy-Mayor performs a transitive relationship that illustrates PV's subordination to the notion of *patrimoine*:

> Solar at the communal level, yes, sure. Yet in Paris we are not sure that we want it to be visible… the idea is to push for architectural integration so that we have solar, without it being necessarily visible. As first tourist destination in the world, after all, we do not want to completely degrade '*l'estethique parisienne*'.
> (Baupin, Denis, Deputy Mayor of Paris, *Conférence des Maires et élus pour le solaire*, event, 15 May 2009)

As will be seen over the course of this chapter, the notion of *patrimoine* is a recurring theme that brings to the fore contradictions between the Mayoral aspirations of sustainable development (such as Paris as '21st century post oil' capital (Mairie de Paris 2006a)), and on the other hand retaining Paris' identity as a "museum city, with quite some monuments" (Energy Advisor 2, *EDIF*, Interview, Paris, May 2009).

However, while the (socialist) Mayor and his green party deputy find themselves caught in this transitive relationship between 'sustainable development' and *patrimoine*, others experience *patrimoine* as a barrier to implementing PV in Paris in a rather different way. For others, especially those who do not reproduce the transitive dilemma that Baupin and Delanoe perform, *patrimoine* acts as a pernicious barrier to PV because of the way that what counts as 'harmonious integration to the built environment' is not left to the popular imagination. Rather, *patrimoine* is concept that is enforced through formal channels, which are experienced by a range of actors as *obstructions*.

5.2.3 Obstruction

> So, in the *Plan Climat* it is stated that solar panels *need* to be installed, in the *PLU* we are told that we are not allowed to install solar panels. [laughs]
> (Energy Advisor, *PASU*, Interview, Paris, May 2009)

At the time of research, solar sympathizers in Paris were faced with a confounding situation. On the one hand, the *Mairie de Paris*'s political priorities were aligned with 'the times', in terms of a commitment to climate change and 'sustainable urban development'. However, on the other hand, there is *patrimoine*, a logic that frames urban development in Paris. The interviewee in the Mayor's office, cited above, framed the situation as a simple contradiction between two strategic urban documents, the existing spatial development plan (*Plan Local d'Urbanisme – PLU*) and the more recent climate change strategy (*Plan Climat*). While the latter commits the *Mairie de Paris* itself to a range of climate-related energy targets (emissions reductions, energy efficiency and renewable energy), the former enshrines a rationale of 'preservation' of the built environment. Specifically, a commitment to *patrimoine* is codified in the *PLU* through the notion of the 'virtual envelope'[51] of buildings. This envelope sets strict height and width limitations that cannot be exceeded by building components. Significantly for PV, the virtual envelope effectively disallows the superimposition of solar panels, as volumetric material building components, onto the city's rooftops and façades (see Figure 5.1). While a process of reform was underway to make compatible the two development vision contained in the *PLU* and the *Plan Climat* (see Section 5.4.1), until this happened the *PLU*'s virtual envelope effectively constituted an obstruction to practically anyone desiring to install PV in Paris.

Such an obstruction can be conceptualised using Callon's (1986b) notion of the 'obligatory point of passage'. In classical ANT such points are central nodes in a network of relations "past which everything else has to file" (Mol and Law 1994). As such they are relational elements, which may or may not have physical substance. Obligatory points of passage act by 'funnelling' different actors' interests and behaviours in such a way that actors "have no choice: if they want to move, if they want to achieve their goals, then they have to do so by making a detour" (Law 1999b: 7) through the obligatory passage point. Inverting this notion of obligatory passage point enables to treat the *PLU* as an obligatory point of *im-passage*. For Murdoch (1998: 362) 'formalisms' such as the virtual envelope "are the most prescriptive of 'scripts' as they often lay down very specific rules of behaviour". As a result, anyone seeking to install PV in Paris must abide by the *PLU*'s virtual envelope, which effectively means that practically no one is able to install PV in Paris as long as the *PLU* is the obligatory point of im-passage.

Obstructions in the form im-passage points also capture the experience of others seeking to bring about innovation in PV beyond the area of planning. The PV industry, and in particular industry lobby organisations, such as the *European Photovoltaic Industry Association* (*EPIA*) and other

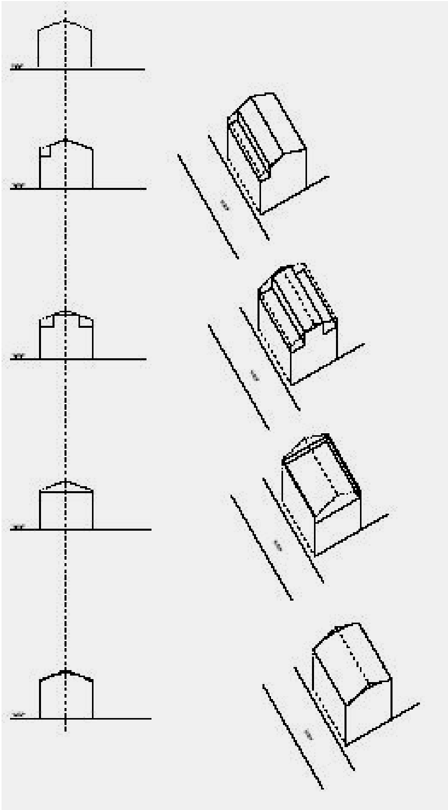
[51] *Le gabarit envelope.*

research establishments such as the EU *Joint Research Centre* (JRC) for a number of years raised concerns over supply side bottlenecks in the PV industry. As an *EPIA* report states, a flowing supply of silicon (the raw material from which the dominant PV type of modules are made) is thought as important for securing the continued expansion of the industry:

> For some years silicon supply (processed silicon) has been the bottleneck of the PV industry… As silicon is a major raw material for c-Si [crystalline silicon] technologies (93 % in 2006), silicon capacities predefine the upper production limit for the industry.
> (EPIA 2008: 6; Global Market Outlook for Photovoltaics until 2012: Facing a Sunny Future)

The silicon bottleneck constitutes a point of im-passage in the minds of those striving for an ever-expanding industry, such as *EPIA*. Besides constituting a limit to production, silicon shortages are also thought to have driven the capital costs of PV modules up artificially, such that prices do not reflect the technology's 'actual' manufacturing costs (i.e. given 'normal' silicon prices) (JRC 2010). Industry fears that, as a result of artificially high prices, demand for PV will decrease, which in turn will affect the PV industry's capacity for fast-paced innovation and rapid price decreases (see Section 4.3.2, which touched upon the notion of 'experience curves' – basically, these relate cost trends to the amount of installed global PV capacity).

As these two examples serve to illustrate, actors may encounter barriers to PV as obstructions which allude to a concentrated form of barrier, experienced by actors as being relatively localised in particular sites (a planning document, a supply chain segment). In contrast, the final type of regime effect, explored in the following section, is marked not by boundaries, hierarchy and accessibility, but constitutes another qualitatively distinct form of barrier in action: the disconnection of elements that are necessary to come into relation for the implementation of urban PV.



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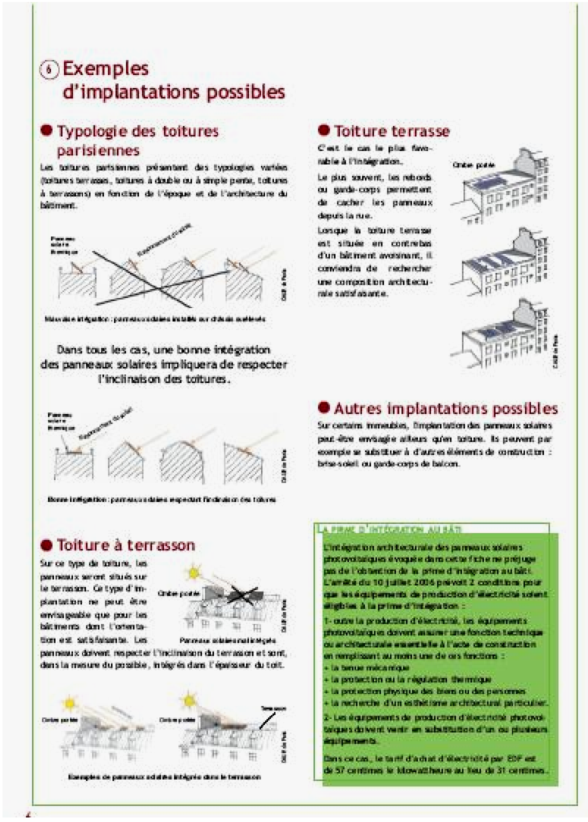

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Figure 5.1 The virtual envelope

(Source: Mairie de Paris (2010) *Installation de panneaux solaires*, [1]#P56; [2]#P84)

5.2.4 Disconnections

A useful way for thinking about disconnection as a barrier is using Annemarie Mol' (2002) argument that the reality of any particular object (whether technological, or a 'disease') is multiple. This already inspired a large part of Chapter 4. Here Mol's argument about praxeological complexity is useful for understanding 'disconnections' between professional practices as one (of potential several) ways in which professional practices may relate to one another – others, for instance, could be 'consistent', 'contradicting' or 'included in one another' (Law 2008b). Examples of disconnections as barriers abound from the research, however they can be seen as chiefly concerned with two types of disconnections; namely that which exists between different built environment professions, which must work alongside one another to deliver PV, on the one hand, and on the other a disconnection between consumers of energy and their (energy unconscious) consumption practices. One specific example of each disconnection is explored in this section – the cases discussed below are chosen as they exemplify the nature and effect of disconnection;

that both cases are from the Parisian in situ research stay is coincidental; analogous disconnections were experienced in Barcelona and London.

The disconnection between different built environment professionals can be well-illustrated by recalling the professional experience of a Paris-based PV professional, who is engaged in testing the performance of building-integrated PV technologies as well as training aspiring PV installers. During the interview, which included a walking tour of his rooftop 'laboratory', the expert explained that a key barrier to implementing PV was to bridge across the different professional realities of roofers and electricians. Traditionally, these not only operate in distinct domains of a building (on the roof and 'inside' the walls, respectively) but, crucially, they also speak different professional 'languages'. The interviewee explained that

> the thing with PV is, with superimposed panels but also especially building-integrated… you have to call in the roofer as well as the energy technician, electrician or others, plumbers, and somehow make them work together… I do think that in the domain of energy people are making efforts to speak the same language as construction. They'll speak of square meters and in terms of weight, because to developers watts don't mean much… you have to bring together the supply chains of energy and buildings, who don't necessarily work together traditionally.
> (PV professional, *CFI*, Interview, Paris, May 2009)

According to the knowledgeable PV expert, energy professionals tend to think of the technology in terms of the electricity demands it needs to be tailored for; in terms of connecting into an array a series of individual modules of set magnitudes of capacity ('peak power', a measure of nominal power output). Importantly, this sort of reasoning may not be readily compatible with building professionals' reality, of calculating structural loads and dimensions of buildings and rooftops, which are more likely to be expressed in weights and surfaces. These distinct professional realities – of kilowatts and kilowatt-hours, on the one hand, and kilogrammes and square meters, on the other hand – mean that there is, at least in the mind of the Parisian PV expert, a disconnection between, broadly speaking, the 'supply chains of energy and buildings'. Translating the different volumetric and electrical implications of the technology into units that are relevant to the other profession's practice may constitute a real challenge, and this sort of novelty may be difficult to assimilate. Analogously, for instance, a UK government technical report notes that during a government funded PV initiative[52] “roofing workmen were cautious to get involved with what they perceived to be electrical work” (DTI 2004: vii).

A different form of disconnection, not between built environment professionals, is made intelligible through the problem-solving utopics of the energy advisors in the 12th *arrondissement's* ‘Espace Info Energie*’* (run by the non-profit *EDIF*). In their advisory capacity to ‘the public’, the EDIF advisors respond to a diversity of queries from a range of publics. The advisors explained that in their interactions with different individuals they had become aware of the fact that most people had very little sense of what renewable energy technologies such as PV were for, or what they could do. One of the *EDIF* energy advisors recounts this disconnection between citizens and energy consumption:

> I once spoke to a person who phoned us to ask, ‘what’s the point of putting in solar panels, because we already have electricity coming out of our plugs here’, saying that that’s what [nuclear] power stations are for… then, other people come to see us, they tell us that they want to install PV to power their [electric] heating. But we know for a fact that that won’t be possible, at least for now and the near future. And especially not over an entire day or year. That’s just not how PV works, and there’s a real concern there, with these people’s lack of understanding.
> (Energy Advisor 2, *EDIF*, Interview, Paris, May 2009) - - 12th arr

The interviewee diagnoses a fundamental disconnection between energy users and new technologies. As with built environment professions, it is a disconnection based on knowledge of the technology; however, rather than based on professional practice, it is framed by another (London-based) interviewee as a “mismatch between expectation and reality” (Project Manager/engineer, *LCCA*, Interview, London, November 2008). In a very basic way, this translates into PV being a technology disconnected from these citizen’s energy consumption practices. The first type of individual mentioned by the energy advisor is unconcerned by PV’s environmental credentials in such a way that the technology is understood as redundant; while the second type of individual is understands PV as required to meet their particular requirements. However, PV’s

[52] The *Large Scale Building-integrated Field Trial.*

electrical properties, dependent on the sun, do not provide a constant flow of power and as such may not cater reliably for heating purposes; in particular not for an old and energy intensive building stock such as the majority of Paris' buildings. In both cases the individuals do not consider that a technology such as PV may itself have implications for their electricity consumption practices, or that in grid-connected form it is not necessarily a priority for PV to be able to meet all electricity demands at all times.

5.2.5 Simultaneous barriers 'in action'

Barriers, therefore, are the heterogeneous effects of regimes – of the relations predating efforts to innovate which become amenable to analysis through exploring them 'in action'. The material semiotic critique of socio-technical regimes as 'locking out' new technologies such as PV is given flesh in the preceding sections through an engagement with actors' on the ground experiences of innovation. The discussion began with rejecting explanations of barriers that locate these unproblematically in the 'social' (or 'non-technical'), 'technical', 'regulatory' (etc.) characteristics of regimes; such as are widely present in policy literatures (Generalitat de Catalunya 2006; EPIA 2008; DECC 2009). Del Rio and Unruh (2007: 1501), for instance, argue that "the barriers that engender lock-out of desirable technologies" are of 'technological', 'organizational', 'industrial/system', 'societal' and 'institutional' character. These categories include a diversity of elements that are no doubt salient elements of barriers. However, beyond providing a list of a string of terms under a set of headings[53] it is open to question what such a description of 'lock out' does in terms of contributing a better understanding of the challenges of innovating. Significantly, such a portrayal risks reifying these as inherent features rather than teasing out the various ways in which regimes are adversely formative of efforts to innovate. As opposed to working with often taken for granted understandings of what might count as the 'technological', 'organizational', 'societal' and 'institutional', a material semiotic account of barriers works through generating metaphors that capture the *experienc*e of innovating 'in action'.

[53] Dominant design, standard technological architectures ("technological"); Routines, hierarchies, customer–supplier relations ("organizational"); Industry standards, technological interrelatedness, value chain relations ("industrial/system"); System socialization, adaptation of preferences and expectations (societal"); Government policy intervention, legal frameworks, departments/ministries ("institutional") (Del Rio and Unruh 2007: 1501).

The four metaphors used in this section are summarised in Table 5-1 with respect to how they make sense of actors' encounters with barriers. Here exclusions work through creating boundaries and thresholds that establish impermeabilities between an inside and an outside. Examples from the research include existing electricity systems, which totally exclude novelty from mattering both materially and discursively and policy set ups (such as the Spanish one) contains a threshold below which electricity generation does not qualify before the law. Subordinations are characterised less by the presence of insides/outsides rather than constituting instances in which transitivities exist between the technology and other states of affairs. Here prevailing cost-driven construction practices and the aesthetical architectural heritage imperatives of urban development in Paris were discussed as examples. While this is not necessarily the case, transitivities may be experienced as obstructions, as in the case of the Parisian spatial development plan. Obstructions are concentrated bottlenecks through which innovators must but cannot pass – even if they are on the 'inside' or PV is not subordinated, as illustrated by the example of raw material shortages. Finally, the metaphor of disconnection is used to understand how those seeking to promote PV encounter existing building an consumption practices as domains of activity that lack integration with energetic concerns. As Table 5-1 illustrates, barriers may singular, however more often than not they are expressed in qualitatively different ways across different actors' utopics. For instance, *patrimoine* as a barrier to innovation derives its strength in this case in the way it simultaneously subordinates and obstructs PV across the utopics of the Mayor and the energy advisors.

This sort of portrayal of barriers draws attention to interrogate the heterogeneity of 'lock out', as simply stating *that* novelty is somehow disarticulated in the context of normalcy falls short of accounting for the diverse ways in which innovators experience 'lock out' in practice. However, diagnosing exclusions (from accessing an 'inside'), subordinations (to other imperatives), obstructions (of impassage points) and disconnections (between domains of activity that require integration) is just the first step for developing a better understanding of how that which is in place shapes the conditions for innovation. In fact, the diversity of ways in which regime effects are encountered by actors draws attention to the need to inquire into the relations that cause diversely experienced barriers. A material semiotic account of regimes (see Section 2.5.3) proposes to interrogate how regime effects are produced, relationally, by a variety of overlapping spatial relations. This is what the following section now turns to, focusing on how the heterogeneity of relations experienced as 'barriers' are entangled in a variety of regime spatialities. Importantly, different regime effects are cast as deriving from a common set of regime spatialities, which are however distinctly expressed within and across Barcelona, London and Paris. As such, the following section proposes an account of regimes that promises to explain variations in barriers to innovation that transcends the ontological fixity of conventional accounts of 'lock out' as generated through 'networks' of meta-aligned regime actors which are situated at particular (often national) 'scales'.

Table 5-1 Barriers 'in action'

	Exclusion	Obstruction	Subordination	Disconnections
Principles	Boundaries and thresholds	Impassage points	Hierarchical transitivities	Practice-based separate realities
Utopics	Problem-solving (CLER) Eco-empowerment (FT)	Livelihood (PV industry) Problem-solving (EDIF)	Leadership (Mayor of Paris) Problem-solving (architects)	Problem-solving (CFI/EDIF)
Barrier	Grid-connection	Supply chain bottleneck, Planning permit	Cost and aesthetic Development priorities	Construction and consumption practices

5.3 Regime spatialities

> …geography matters for sustainable innovation, but research is only beginning to explore how this geography influences transitions.
> (Smith et al. 2010: 443-4)

This thesis concurs with Smith et al.'s call for amore explicit engagement with the 'geography' of innovation; however, in so doing it proposes a fundamental departure to *how exactly* 'geography' might matter is currently understood in the innovations literature. Critiquing prevailing understandings of geography in innovation studies, Chapter 2 (specifically Section 2.2.4) argued that in generating a confounding variety of spatial imaginaries[54] several otherwise thoughtful contributions in the literature have fallen short of providing a convincing account of the geographies of innovation. How geography matters for innovation is cast in this section as deriving from the way in which spatial relations that predate efforts to innovate generate barriers (thus understood in the previous section as 'regime effects'). Here it is argued that being attuned to the geography of innovation is fundamental to understanding how particular relations become experienced as barriers to innovation. For instance, when asked about the causes underlying the disconnections between energy users and their knowledge and grasp of electricity, the two Paris-based *EDIF* interviewees referred this to a matter of 'culture', 'energy culture' – or rather a lack thereof. The energy advisors attributed this to the fact that the topic of 'energy' as a matter of concern had simply not featured significantly as an issue, historically speaking, *in France*:

> It's true that in France energy has been cheap and abundant, and I think that's really specific to France. We've had this nuclear capacity, very abundant and rich… it's become a habit, a bad habit of wasting energy…. The problem is that French people aren't used to energy being an issue.
> (Energy Advisor 2, *EDIF*, Interview, Paris, May 2009) - - 12th arr

Interestingly, the advisors both articulated the problem of lacking 'energy culture' as a typically 'French' phenomenon. Intuitively this link makes sense: historical patterns in electricity supply (cheap and abundant) are to blame for the 'bad habit of wasting energy' – and this is 'really specific to *France*' and '*French* people' because of the features of French electricity supply (nuclear; that is 'cheap and abundant'). However, this congruence between energy consumption practices, features of the electricity supply, and the national territory that the energy advisors inadvertently perform raises important questions about whether this is an essential conflation that holds true in other places as well. Evidence suggests it does not – 'energy culture' is at other times understood as an 'urban' phenomenon, as in the case of Barcelona's municipal authority, for instance, speaking of Barcelona's 'new energy culture' (Ajuntament de Barcelona and AEB 2007).

[54] There is reference to 'macro' landscapes, 'meso' regimes (often at the 'national scale' (Geels 2002), 'local' (Raven 2005) and 'grassroots' (Seyfang and Smith 2007), 'networks' of niche regime actors (Schot and Geels 2008), and the 'regional' (Späth and Rohracher 2010), 'urban' (Hodson and Marvin 2010) and 'community' level (Smith 2010).

To develop a material semiotic understanding of how it is that barriers, such as the disconnection of French energy consumers from a more energy-aware form of consumption, come to take particular geographical forms (in this case, a territorial congruence with the French state) a brief excursion into how geography has been treated, explicitly or implicitly, in the prevailing literature is necessary.

When it comes to conceptualising the geography of innovation in the innovation studies literature, different approaches can be seen as falling into two broad categories. On the one hand, there are those which treat geography as a largely implicit aspect of innovation (e.g. Schot and Geels 2008; Van Driel and Schot 2005; Verbong and Geels 2007; Rotmans et al. 2001). Here spatiality tends to be taken for granted rather than interrogated. For instance, Geels (2010b) situates socio-technical regimes at the national level, based on what he argues are historical patterns of nationally organised infrastructural provision. Whatever the accuracy of this particular assessment, this way of thinking has resulted in rather narrow intra-disciplinary debates focused upon 'unpacking' and 'unpicking' interacting nests of niches and regime at various different spatial 'scales' (Genus and Coles 2008). Rather than interrogated, here the notion of 'networks' of actors and 'territorial' geographies of the state, region and locality have effectively acted as ontological spatial 'master concepts' (Leitner et al. 2008) – the implicit 'units' of innovative activities, which – somehow, but with difficulty – 'interact' in practice. On the other hand, there are more recent contributions (mostly from beyond the immediate discipline of innovation studies) which are beginning to grapple with the importance of space as both shaping the content of innovation (e.g. economic geographers Coenen et al. (2009)) as well as how processes of innovation are themselves tied up with the emergence of particular spaces (e.g. Bulkeley et al. 2010; Smith 2010; Hodson and Marvin 2007). Against this background, this section's interrogation of regime spatiality can be understood as falling into the second category of contributions.

It aligns with human geographical theorisations of space which caution against taking for granted "the boundaries that organize our world as given and natural" (Ollman 1993: 38). While 'spatial' debates in human geography are complex and largely ongoing, there has been a trend against 'ontologising' (Leitner et al. 2008; Howitt 1998) spatial categories, such 'territory', 'place', 'scale' and 'network' and rejecting analytical strategies that "swerve from one fashionable spatiality to the next" (Leitner et al. 2008: 158). In other words, rather than singular and ontologically fixed, spatial relations are understood as enacted, at times even 'crafted' (Fraser 2010). Urban geographer McFarlane (2009; 2011) proposes to decentre the dominance of the discipline's established concepts in favour of a more neutral form of association, that of the 'assemblage' which purports to create scope for a variety of spatial imaginaries to take shape and provide greater sensitivity to how actors themselves deploy spatial categories in their discourses and practices (McFarlane 2009). This resonates strongly with material semiotic scholar Jensen's (2007: 833) proposition to conduct an analysis attuned to how "actors engage in a constant deployment of their own scales[55]". For the present purpose this implies abandoning a concern with uncovering the 'right' spatial lens through which to analyse innovation (i.e. networks of niche and regime actors, or the territory of the nation, the city), as is typical of the first category of innovation studies' approaches to space. Rather than a passive backdrop, spatial analysis is used as a *means for explaining* innovation as scholars such as Hodson and Marvin (2010) and Bulkeley et al. (2010) falling into the second category of researching innovation from a spatial perspective are beginning to do. This is the strategy employed at present. Over the course of this section a range of existing spatial metaphors are mobilised to generate insights into how heterogeneous relations are entangled in ways that engender specific barriers to innovation.

Concretely, this section explores four forms of regime spatiality: *networks*, *scales*, *places*, and *urban assemblages*. The four regime spatialities are the four spatial forms that were found as causing barriers to innovation in urban PV; however, they indicate the level of spatial complexity involved in innovative processes, rather than necessarily an exhaustive treatment. As with barriers 'in action' explored in the previous section, these four regimes spatialities are not intelligible independently of innovative practices – they derive their significance from the way in which they can be traced as the causes of the heterogeneous barriers to innovation explored in the previous section – exclusion, subordination, obstruction and disconnection. As such, this section treats regime spatiality as emergently intelligible through innovative practice – utopics – itself. Crucially, treating the geography of innovation as emergent implies accommodating the possibility that spatialities coexist, overlap and intersect in the process of innovation. Hence this section's title, 'regime spatialit*ies*'.

[55] Jensen uses 'scale' in this passage intends to destabilise the 'scalar' micro-macro binary; however Jensen's statement and general position can easily be read as concerned with general forms of relationality as opposed to the way in which 'scale' is construed in human geography debates.

5.3.1 Networks

The starting point of regime analysis is usefully placed at where existing frameworks in innovation studies cease to generate insight. The prevailing (albeit often implicit) spatial forms that have received attention in frameworks such as the *SNM/MLP* are those of the 'network' and the 'territory'; however, with little systematic interrogation into how these might relate in practice. In *SNM/MLP networks* of regime actors are thought to operate at the territorial level of the *nation* – whether this has to do with the assumption that infrastructural systems operate at this scale (Geels 2010b) or because of *SNM/MLP* seeks to inform "nation-state policy audiences" (Smith et al. 2010: 443). Contributions that have 'added' additional geographical imaginaries (e.g. Geels and Raven 2006; Seyfang and Smith 2007) have done little to shed light onto how the complex relationship between networks and territories results in important barriers to innovation. In part the difficulty of unpicking and unpacking regimes, as noted by Genus and Coles (2008), has to do with the fact that simply adding spatial imaginaries to the list fundamentally fails to interrogate how these two spatial forms – networks and territories – may in fact be tied up with one another, co-constitutively. In contrast, classical ANT explicitly deals with this territory-network relationship by understanding territories (or, 'regions', in the ANT vocabulary) as effects that are generated through networked relationships. Based on this understanding, it becomes possible to elide the narrow debate of situating networks at territorial scales, as has been the tendency in the literature. Instead, regime analysis is urged to focus on understanding the territorial extent of regimes through understanding territories as integrated through networks.

It was already explored in Section 5.2.1 that in France the state-sponsored 'all-electric, all-nuclear' electricity supply logic acted for a long time to exclude non-centralised power generation technologies, such as PV through pure illegality. Given the territorial congruence of powering operations and the French state, the strict demarcation between supplier and client effectively constituted energy consumers (cities, villages, households) as energy demand centres on a *national* basis. This works both in terms of excluding and obstructing PV access to the grid, as well as disconnecting energy users from the act (and thus the impacts) of generating power. A similar national regime of electricity is enacted in the case of electricity in London-UK. However, this is not so much an effect of the close relationship between utility and state, as in the French case, but rather an artefact of national policy. While historically integrated, nowadays the UK's electricity sector is much more liberalised than the French one, with several utilities (the 'big six') supplying power on a more regional basis. Through national policy, however, a national regime can nonetheless be seen as taking shape. Nowadays this is enacted, most notably, through a state policy on renewable electricity, the Renewables Obligation (RO), which has been the main policy instrument for financially rewarding the sale of renewable electricity. Introduced in 2002, it consists of a requirement imposed upon existing electricity generators to source a (annually increasing) percentage of their electricity supply from renewable sources[56]. It effectively subordinates small scale renewable generation in the way it rewards generators a unit price for each megawatt-hour of electricity. As the following interviewee from a south London-based non-profit energy agency explains, for a standard household scale system (of approximately 2 kilowatt peak)

> you generate about 1000 kilowatt hours [1 MWh] and get 45 pounds a year, and the administrative things of putting in the ROC meter, that costs £250, so you've got several years payback just on your meter [laughs]… you're better off by just, not even plugging it in [to the grid], you may as well just plug it into your ear. [grimaces]
> (Senior Project Manager at CEN 2008, London, November 2008)

The RO subordinates PV power on a national basis, performing a national regime as in the French (utility-state) and Spanish (*Real Decreto*, see Section 5.2.1). However, while the French and Spanish cases work to *exclude* (small scale) urban PV as a grid-connected electricity generator, in the UK the barrier encountered is one of subordination; distinguished by the way in which PV power is legally allowed (however not financially viable) under the RO.

The Barcelonan case, however, alerts to the possibility that network regimes do not necessarily or even exclusively enact a national regime spatiality. While the national *Real Decreto* excludes across all Autonomous Communities, electricity generation is a much more regionalised phenomenon in Spain, owing to how the electricity sector was carved up following the Spanish Civil War (1936-39):

[56] Through own activities, or the purchase of 'green certificates' from other renewable electricity generators.

> after the civil war they [General Franco's government] gave the entire cake to the big players, those which helped Franco and the small ones had to close… What happened with renewables is that they're victims of this legacy.
> (Activist-academic, *Josep 'Pep' Puig*, Interview, Barcelona, March 2009)

In addition to being largely excluded under the first *Real Decreto*, in Catalonia another barrier to PV is experienced in terms of the obstruction that emerges as a product of the historical proximity between regional economic elites. The following extracts from an interview with an energy agency employee in Barcelona serve to illustrate how the regionalised character of electricity generates obstruction to PV in Barcelona-Catalonia:

> The [energy] market is *supposedly* liberalised [emphasizes and gestures quotation marks]. But it's not really, and while this is the case big companies will always do what they want, like charge a lot for connecting to the grid… I think that decentralizing energy is something that scares them [utilities], because somewhere someone will stop earning money. With wind energy it's different, utilities have a finger in that pie. Wind parks are in the hands of either utilities or big construction firms which are practically in bed with the utilities, a very incestuous group. But solar at the moment goes against fossil fuel interests.
> (Engineer 2, *Barcelona Energy Agency*, Interview, Barcelona, March 2009)

Through the metaphor of networks interrogating the relationship between the spatial concepts of networks and territories it thus becomes possible to makes sense of how PV is experienced as facing a range of barriers as a new electricity generator in established electricity systems. While electricity 'systems' constitute networks, in the conventional sense of the word of material infrastructures mediating flows, they give rise to a territorial geography of powering. This networked territorial geography of electricity is simultaneously *exclusionary* of technological novelty, *obstructs* access to the grid, and *subordinates* small scale power to larger generation capacity, and effect to disconnect energy consumers from the implications of their consumption practices (see 5.2.4). A careful interrogation of both the material and territorial implications of existing configurations in electricity shows that its territorial geography is constituted by networks of ('out of town') power stations, transmission lines and powerful institutional alliances between state and utility. These findings suggest that the nation is an important territory constituted by networks, however, that caution must be exercised to not assume this prior to analysis as networked regime relations may work across several territorial units, even simultaneously in the case of Barcelona-Catalonia-Spain.

While much of current *SNM*/*MLP* scholarship ceases to inquire into spatial questions beyond the 'energy system', the remainder of this section explores three further forms of regime spatialities which effect barriers to innovation in urban PV. The following section turns to the spatial imaginary of 'scale' to explore how a range of barriers to PV emerge as the effects of nested territorial scales of activity, beyond the networked spatiality of electricity systems.

5.3.2 Scales

The notion of scale forms an important aspect of the entire discipline of geography, having been re-conceptualised several times, almost abandoned (Marston et al. 2005) and 'salvaged' (Jessop et al. 2008). It is not the intention at present to engage in what is a complex and ongoing debate about the merits of scale (Peck 2002; Hoefle 2006; Jonas 2006; Collinge 2006; Escobar 2007; Leitner and Miller 2007; Jones et al. 2007). Instead, scale is here used as a spatial imaginary that explores spatial relationality as "a hierarchical scaffolding of nested territorial units stretching from the global, the supranational, and the national downwards to the regional, the metropolitan, the urban, the local" (Marston et al. 2005: 416). Akin to the regime spatiality of the network, scale is thus understood as integrating territory, however it does so in a hierarchical rather than 'flat' (Marston et al. 2005; Jones et al. 2007) manner. Importantly, concurring with more recent elaboration of scale as relationally intelligible and 'crafted' (Fraser 2010), from a material semiotic perspective scale can be understood as a form of spatial relationality that is enacted, rather than ontologically fixed. As illustrated in this subsection, barriers to PV emerge at the intersection of different nested geographical scales which engender barriers for innovators across London, Paris and Barcelona as a result of local (district and borough) to urban, national, and global inter-scalar exclusions, subordinations obstructions and disconnections.

A first of such inter-scalar regime effects occurs at the intersection between what actors understand as the 'global' character of the PV supply chain (see Figure 5.2) and the industry's dependence on 'national' policy frameworks. In Section 5.2.3 it was noted that the PV industry faces an important obstruction in terms of the upstream unavailability of solar grade silicon. At present a barrier of disconnection that can be added to the challenges facing the industry in terms of the scalar relationship that emerges in the distinction performed between PV supply and demand dynamics. On the one hand, several PV industry spokespersons have described PV as a "very globalised market" (Anta 2008. **#B37**), that "PV supply has had a very global feel to it", characterised by "a handful of very large manufacturers, you know, it's been relatively concentrated (Project manager, *Solarcentury*, Interview, London, November 2008). The 'global feel' of the industry is cast as deriving from the way in which different steps of supply chain are spread across the globe, with "a centre of gravity… currently situated in Asia" (*ADEME* 2006. **#P6**) – silicon mining and refining, melting and 'ingot'-growing[57], wafer-slicing, cell production, module assembly, and wholesale and end user retailing (see Figure 5.2). However, while supply is understood as a globalised industrial activity, demand for the technology, in contrast, is frequently understood as a national phenomenon. This is related to demand being driven by nation state technology support schemes, effectively placing the national as a scale that shapes developments at the global scale of the industry. As this *EPIA* report states,

> PV market deployment is to a large extent dependent on the political framework of any given country. Support mechanisms are defined in national laws. The introduction, modification or fading out of such support schemes can have profound consequences on PV industries.
> (EPIA 2008: 2; Global Market Outlook for Photovoltaics until 2012: Facing a Sunny Future)

The importance of the global/industry-national/government relationship for PV innovation is illustrated by both instances of new commitments being made, for instance, in terms of policy support mechanisms (as in the case of France entering the 'solar power race' and the industry learning lessons 'in the Spanish sun'; see Figure 5.3), as well as through considering what occurs when national governments withdraw financial support policies that were put in place previously (illustrated, for instance, in press material reproduced in Figure 5.2 and 5.3). With "market development often almost entirely dependent on government support" (Euractiv 2008; **#G5**), important disconnections between the ambitions of the global industry and national governments can exist that hinder industry development.

[57] Solid blocks of semiconducting material.

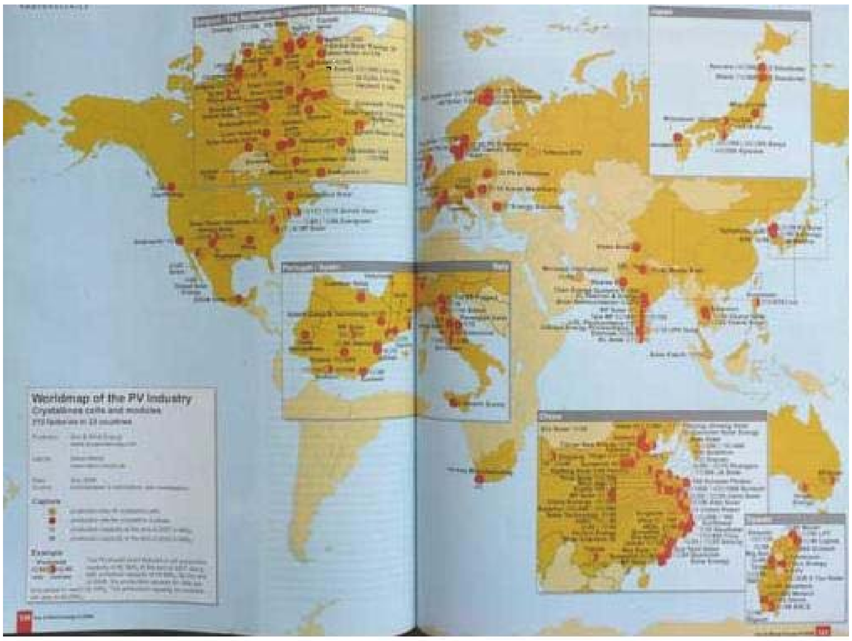


Figure 5.2 Worldmap of the PV Industry (silicon-based PV supply side)
(Source: Sun &Wind Energy. International Issue 04/2008; **#G14)**

1

2

"In September the government abruptly changed course, cutting payments and capping solar construction. Puertollano's brief boom turned bust. Factories and stores shut, thousands of workers lost jobs, foreign companies and banks abandoned contracts that had already been negotiated."[1]

"Yesterday's (23 July) announcement by French electricity giant EDF that it will build the country's largest solar manufacturing plant signalled France's bid to become one of the world's leading solar markets."[2]

Figure 5.3 'Boom and bust' or 'entering the race'

(Source: New York Times 2010, Solar Industry Learns Lessons in Spanish Sun. **#B131**; Euractiv 2009 *France enters solar power race.* **#P40**)

In contrast to the global-national dynamic a different scalar relation is evoked by solar innovators in Paris. Here a politics of scale operates between the 'local' and the 'national'. To recall, above the notion of *patrimoine* was introduced as a logic guiding urban development that subordinates PV and other 'sustainable development' technologies through being formally enshrined in the city's spatial development plan (*PLU*). Little was said, however, about the ways in which *patrimoine*'s exclusionary effect as an urban development logic is related to its institutionalisation into national law. In France *patrimoine* is governed by the state Ministry of Culture through a set of principles that are 'scientifically and legislatively' determined and formalised in the national 'Code du Patrimoine' (Utard 2005). These are translated into locally applicable guidelines in each localities' spatial development plan (e.g. the *PLU*'s virtual envelope). On the other hand, the national principles are enforced through the professional body of the *Architectes des Bâtiments de France* (*ABF*s), who are (appointed, not elected) civil servants attached to the Ministry of Culture. The consequence for implementing PV is that the *ABF*s' binding verdict is often the source of obstruction, as planning permits are frequently refused in areas that fall under the state's definition of *patrimoine*. Considering the high density of *patrimoine* sites in the capital, the vast majority falls under the jurisdiction of the *ABF*s. The following interviewee from a Paris-based non-profit explains how, at the time of field research, the presence of the *ABF*s was perhaps the single most salient feature inhibiting PV in Paris:

> the *Architectes des Bâtiments de France*, you know the principle, one person has the power to block any project, and they're not democratically elected… they're one of the key obstacles to getting any [PV] work done… The state comes in to decide over local matters, while normally it's the *élus locaux* [local representatives, councillors] who should be granting planning permissions.
> (Director at CLER , May 2009, Paris)

The precedence that the national civil servants take over local planning authorities suggests that significant barriers may face innovators when development priorities are fought out as governmental authorities at different scales compete over urban space. In this case, PV is often excluded from mattering across the city of Paris.

This sort of scalar conflict is not only a feature of national-urban but may also manifest itself in dealings between the urban and sub-urban authority, as in the case of Barcelona and London. In both cases, the delivery of the *Ajuntament*'s and the *GLA*'s municipal PV project encountered difficulties with respect to getting on board the Barcelonan district's Technical Services and some borough planners to authorise the projects. Just like the *ABF*s jurisdiction over Paris' *patrimoine*, the borough planners and Technical Services (mostly architects) effectively act as gatekeepers to the local building stock. For instance, when the *Ayuntamiento* put the newly created Barcelona Energy Agency (*Agencia Energetica de Barcelona - AEB*) in charge of delivering a series of PV installations on municipal buildings in 2002 the *AEB* staff encountered significant problems with securing the cooperation from the sub-urban districts' technical services, which are in charge of the maintenance of public buildings at the local *distrito* level (this is also recounted in Caamaño-Martín 2009)). The following *AEB* engineer, involved in the projects, explained that delivering the series of PV installation was a 'tough fight' with the district architects:

> the [district] architects were telling us, 'no inclination of the panels!'. But panels without inclination, apart from being less efficient, also don't clean themselves. What did we do? Well, it was a fairly tough fight in this regard!... The majority of architects still live in the era of pyramids [laughs], where the only thing they do is put stone upon stone… It's a problem of training. On the curriculum of architects renewables don't exist.
> (Engineer 1, *Barcelona Energy Agency*, Interview, Barcelona, March 2009)

In this case the inter-scalar conflict plays out as a barrier of disconnection – the Technical Services were reluctant to engage with the technology as there was a very basic disconnection between them and PV, owing to their lack of training in energetic matters. This lack of professional capacity stands in contrast to the case of London, where inter-scalar regime relations relate to a rather different issue. In contrast to the largely logistical role of the district Technical Services in Barcelona, local London boroughs have well-defined executive planning powers within their boroughs, which may – as in the case of *ABF*s – result in PV being refused planning permission. This *LCCA* interviewee involved in the installation at City Hall recounts the difficulties faced by the *LCCA* team to get planning approval for the system:

> quick decisions are made in a planning committee meeting! Originally we were going to have standard BP framed modules. That was the first design that went forward and that was kicked out by the planners. Southwark [planners] said they wanted a much more aesthetic looking roof rather than one with rectangular panels, so that was a design change to unframed trapezoidal glass… while we may say one thing, the boroughs may say something different. They themselves have their own individual planning requirements.
> (Project manager/engineer, *LCCA*, Interview, London, November 2008)

The scalar relationship between the (Southwark) borough-level planners and the *GLA*-level *LCCA* project management team constitutes a similar local-urban inter-scalar conflict; however, in more significant ways the example bears similarities to the Parisian *ABF*s' role of stewards of the national *patrimoine*. Specifically, it is the interviewee's reference to the subordination of PV to notions of aesthetics through which parallels can be drawn to the Parisian case. While in both instances a scalar spatiality is performed, the similarities between the cases alert of another, related but distinct form of spatiality: that of 'place'.

5.3.3 Places

A third spatial regime causing barriers to innovation in urban PV derives less from inter-scalar relationships than from what Massey (1991) calls a 'sense of place'. Places, according to Massey are concentrated yet loosely coherent

> constellation of social relations, meeting and weaving together at a particular locus… these relations take a further element of specificity from the accumulated history of a place, with that history itself imagined as the product of layer upon layer of different sets of linkages, both local and to the wider world.
> (Massey 1991; unnumbered version).

In both cases of *patrimoine* in Paris and the PV installation at London's City Hall place-based relations are the cause of barriers to PV; however in rather different ways. In the latter case, the obstruction constituted by the (initial) planning refusal by the planners of the London Borough of Southwark, while made possible through the scalar relationship between the *GLA* and the borough, is intimately tied up with the place-specific articulation of the relationship between urban architecture and regeneration in Southwark. This has been framed in the following way by (then-) Councillor Catherine Bowman:

> Architecture has played a huge role in Southwark's transformation. Only 20 years ago, the borough played second fiddle to the City and West End, yet today it stands as the cultural centre of London.
> (Catherine Bowman, (then) Executive Member for Regeneration & Economic Development, Southwark Council, London SE1 2004; **#L126**)

A place-based spatiality emerges through Southwark planners' striving for the 'harmonious' architectural blending of the PV system with the building at City Hall. However, while for the *GLA* and its architects, the PV system "completes the building as originally designed… sustainable, virtually non-polluting public building"(Fosters + Partners http://www.fosterandpartners.com/), for *Southwark Council* PV is subordinated to questions of regeneration – similar to other 'cultural institutions' such as the London Eye, the London Aquarium, the Shakespeare Globe and National Theatres, PV at City Hall may be seen as serving as a 'cultural anchor' for regeneration by contributing to the cultural production of the Southbank of the Thames in London (see for example, Hamnett and Shoval 2003; Teedon 2001; Baeten 2001). A place-based regime of regeneration may effect to obstruct in planning committee, and beyond these it serves to subordinate PV to priorities of monumental architecture characteristic of regeneration in Southwark, a policy Southwark Council has pursued over the last couple of decades.

As opposed to Southwark's place based regime of regeneration, in Paris place space is enacted according to a rationale of the *preservation* of the built environment. What precisely counts as *patrimoine* is narrowly defined by the 'co-visibility' clause in the national 'Code du Patrimoine'. This formalism draws a 500 meter radius around any heritage site (such as 'historical buildings' – the highest form of protection (the Eiffel Tower, the Louvre Museum), or those 'registered in the supplementary inventory', where only a part of the building itself is listed (e.g. staircase, facades, windows)). The regime of place is thus centred around specific *patrimoine* sites, however exceeds them by the 500 metre co-visibility radius. While *patrimoine* is enforced through the scalar relationship between the national and the urban-local, the significance of *patrimoine* (expressed both through co-visibility and the 'virtual envelope' in the *PLU*) can be attributed to events of several decades ago, as a response to the ‘new urbanism’ current prevalent in post-war France – “a national and unsentimental political will expressed in a strident and aggressive rhetoric of necessary change and progress […] hostile to pleas for prudence or preservation” (Jordan 2004: 105). Jordan (2004: 108-9) notes that an iconic moment that marked a turning point was the controversy over the redevelopment of *Les Halles*, a historical market in the centre of Paris, which got caught up in the “renewal frenzy of the 1960s” [58]. While popular attempts to salvage the site were largely unsuccessful, on the whole the effect was a revival of “a new sense of historical preservation”, which is very present nowadays. The “nostalgic modernism” (Wakeman 2004) of *patrimoine* effectively generates a Parisian ‘sense of place’ – and, at the same time effectively stifles climate-related upgrades of the built environment (insulation, window replacements, energy efficiency and renewable energy technologies). *Patrimoine* as a barrier to innovation derives its strength in this case in the way it works to subordinate PV to the logic of preservation, which in turn is enforced through the obstruction of planning permits and further disconnected from the rather energy unaware professional body of the *ABF*s.

In conceptualizing the regime of place attention is thus drawn to material-discursive productions of particular sites as specific and somehow ‘unique’. They acquire their significance, their ‘sense of place’ from their “accumulated history” (Massey 1991: unnumbered). However, as geographers Jessop et al. (2008: 391) note, “processes of place production are constitutively intertwined with the territorial, scalar, and networked dimensions of sociospatial relations”. This begins to draw attention to the way in which places like Southwark’s City Hall and areas of *patrimoine* are not sites that are somehow set apart from other forms of spatiality; rather as specific places they are emergent through intersecting spatial forms. This intersection will be interrogated in depth in Section 5.3.5. At present, a final regime spatiality is explored, which further complicates the singularity and separability of regime spaces: that of urban assemblages.

[58] *Les Halles* was razed to the ground based on the need to link the Métro and the suburban RER train lines underground.

5.3.4 Urban assemblages

> The trouble is, in most of what we will still be living in, working in for another 50-90 years, is already built, it's already standing up and it was never designed to have PV put on it… so whilst Microsoft could talk about a pc on every desk, if your desk wasn't big enough, you got another desk, that wasn't too bad, but if you talk about PV on every roof, if your roof isn't quite right, you can't just get another roof…
> (Project manager, *Solarcentury*, London, November 2008)

The durability of the urban building stock urban materialities is just one of several instances in which pre-existing relations are tied up into urban assemblages, in which existing sociomaterial rhythms become consequential for those seeking to implement PV. Compared to other geographical spatial metaphors, such as territories, networks, scales and places, the notion of assemblages is "not very well elaborated" (McFarlane 2011: 204). However, for the present purpose, it is a useful imaginary for capturing a fourth kind of regime spatiality in the way it evokes a concern with "the milieu, or specific arrangement of things, through which forces and trajectories inhere and transform" (McFarlane 2009: 562). This kind of metaphor draws attention to a set of semi- or incoherent instances of various material and discursive processes which lack a central organizing principle (Farías 2009). For instance, understanding the city as an assemblage enables an emphasis simultaneously on "the material, actual and assembled, but also on the processual and the multiple… as a tourist city, as a transport system… as a festival, as a surveillance area" (etc) (Farías 2009: 14). In the most basic way, therefore, entire cities can be understood as assemblages, as some scholars have (Farías 2009; McFarlane 2011). For instance, as in the above quotation, London can be understood as an urban assemblage of buildings with a renewal rate of several decades. This constitutes a barrier to PV in the sense that PV is easiest to accommodate in new buildings, where it can be integrated optimally in terms of orientation and angle. The renewal rate of the building stock of large cities, such as those researched, is relatively low in general, however, this is particularly pronounced in Barcelona:

> Barcelona's solar potential is enormous. But, despite this, we don't have much roof space… Barcelona is a compact city which won't grow much because it can't, it only grows upwards and not a lot at that because the building stock is very old.

(Engineer 1, *Barcelona Energy Agency*, Interview, Barcelona, March 2009)

More than any of the other spatial forms explored above, the notion of assemblage draws attention to the way in which particular sites emerge at the intersections of different sociomaterial "habits of practice, ways of going on, and trajectories" (McFarlane 2011: 209). As places of work, education, residence and leisure cities are made up of a wide diversity of buildings that operate according to various different everyday 'rhythms' of living, working, and consuming; such as schools, social housing, central urban areas, new developments and shared ownership buildings.

This translates, for instance, into very diverse demands for thermal comfort and lighting. Generally speaking residential dwellings display electrical and thermal peaks in the mornings and evenings of weekdays, places of work are electrically intensive during office hours and places of leisure display high demands mostly outside of formal working hours and days. On the other hand, climatic factors differently shape energy demands for thermal comfort and lighting (in a mid-latitudinal European context, high in summer for cooling and lengthier for lighting purposes in winter)[59]. Illustrating how the seasonal aspect of power production and anthropogenic activity is seen as ill-matched (in this case in the context of school buildings), this London-based architect comments:

> the problem with schools is summertime, when there's least loading, obviously, because of school holidays, but that's the time when you're generating the most energy. In schools in particular, on other projects I imagine it might be different, like housing, where demand is, you know, continuous.
> (Architect 1, *Jestico Whiles*, Interview, London, November 2008)

Schools are a particular type of urban assemblage, which is characterised, in this case with low electricity demand at times when output from PV is highest (i.e. in summer). The difference between the demand profiles of different assemblages and the power output profile of PV technology frequently results in the technology being either fully excluded or subordinated to the requirement of matching power loads with demand. While schools are generally cases where PV is being 'retrofitted' after the building has already been completed, new developments constitute

[59] Illustrated by the contrast between Mediterranean Barcelona and mid-latitudinal European cities of London and Paris.

another form of urban assemblages which may constitute a regime to innovative utopics. In the case of London, for instance, it is the size and 'energy density' (that is energy demand per square metre) that is the assemblage that comes to bear upon PV as a regime. A consultant from a large London-based engineering consultancy explains how PV is not seen as able to cater for the energy density of large new developments in London:

> If you look at one of our projects down in Greenwich peninsula, it's very high density. With PV you need to use absolute massive areas of photovoltaics and you need to cover the facades… so it doesn't makes sense… technologies [like PV] are better suited at meeting lower energy densities, it is very difficult to harvest these diffuse energy sources to meet the energy densities required.
> (Engineering consultant, *Buro Happold*, London, November 2008)

As a relatively more spatially diffuse electricity generator that produces a set amount of electricity per square meter, given a particular, geographically dependent, solar radiation budget, PV becomes subordinated to larger 'infrastructural' scale solutions such as combined heating and powering (CHP) which are more easily fitted around the power requirements of the building. Existing construction practices, urban planning requirements, the future purpose of the building, architects, contractors and clients all form part of the assemblage regime which effects to subordinate (and frequently exclude PV).

While in this case the assemblage regime works through a rather narrow definition of what is required to power the building, even in cases where there is an explicit and purposeful requirement to 'be green' urban assemblages may effect barriers to PV. The case of social housing blocks of flats in Paris, for instance, constitute an instance in which the purpose of the urban infrastructure is orientated according to priorities that supersede purely energetic or environmental considerations. In Paris, social housing trusts (*bailleurs socieaux*) have historically demonstrated a fairly strong commitment to environmental performance both in new constructions, which constitute a large part of new developments in the capital, as well as through retrofitting the existing social housing stock. However, despite commitments to 'sustainable development', social housing associations such as *Paris Habitat*, *OHLM* and *SIEMP* generally subordinate PV to solar thermal heating panels. These two *EDIF* energy advisors (of an *arrondissement* with a proportionally larger share of social housing) explain that solar thermal is simply better-suited to social housing buildings:

> Interviewee 2: Reducing one's energy bill, that's a priority for more 'social' neighbourhoods. Here they really want to reduce it because these are expenses that they cannot bear. [in contrast] PV is a source of revenue in France. It's a re-sale, it goes straight into the wallet. One's more for production, and the other… [is interrupted by second interviewee]
>
> Interviewee 1: well two completely different logics, one of consumption and one of production. It's a caricature, but it's true, I've seen it.
> (Energy Advisor 1 and 2, *EDIF*, Interview, Paris, May 2009)

While both technologies effectively reduce fuel bills, they do so by different means. PV, with higher capital investment costs compared to the financially less onerous solar thermal systems is cast as a technology that *generates* income, while thermal heating directly *reduces* fuel bills. Thus enacted as a technology for the 'fuel rich' (while solar thermal collectors are cast as a technology for the 'fuel poor'), those seeking to install PV in the city are having to navigate the complexities of the urban assemblage of social housing, including social housing tenants, blocks of flats, *bailleurs socieaux*, the *Mairie de Paris*, taxpayers (and many others) – with difficulty, as evidence suggests.

While assemblages may thus effect subordination and exclusion, they may also work in an entirely different way as regimes to innovation in PV. The case of the Parisian shared ownership dwellings, *copropriétés*, in contrast to social housing blocks, *copropriétés* tend to house the 'fuel rich'. It is, rather, the way in which collective investment decisions are made within the 'copro' set up that disconnections between the variety of parties involved become meaningful. The energy advisor in charge of the 'copro' PV projects orchestrated by the *Mairie de Paris* explained that these include a variety of different parties, each who have a stake in the maintenance of the building (of public spaces, lighting and elevators): individual flat owner-residents (who want "to make the most of their building in terms of energy performance"), the buy-to-let landlord (who "doesn't live there, who, well doesn't really care, to put it bluntly"), the council representatives ("they are people with responsibilities within the *copropriété* and as such they are generally sceptical") – amongst others.

With only one annual meeting, the institutional structures in place for making collective decisions at the level of the building are not geared towards speedy resolutions. Another Paris-based energy advisor caricatures how decision-making is a lengthy drawn out process:

> [mimicking an exchange between members of a 'copro' committee using different voices]
> So in the first year, they will establish that there is a problem, and ask 'what do we do about it ?'
> So, 'listen, we need a study'
> 'Ok fine, what kind of study?' We'll see next year'.
> Ok, next year, say they've chosen the type of study, vote on it. But, what kind of organisation should do it?
> Comes the third year, the organisation did this and that. 'So, should we do it, or not? Yea, ok, or no'.
> [resumes to normal]
> So all of a sudden, it's been four years… Four entire years to ponder whether to do anything and then after four years the works and all of that still need to be done. It's really very long to implement, and it's particularly pronounced in Paris, which is a very urbanised zone and so where there are a lot of *copropriétés* and that makes it a really lengthy enterprise. A very messy problem.
> (Energy Advisor 2, *EDIF*, Interview, Paris, May 2009)

The heterogeneity of the 'copro' assemblage and its particular way of aligning its diverse constituents is cause of important barriers to those seeking to bring such projects to completion. 'Copro' initiatives constitute another case (as with schools, new developments and energy dense central urban areas), in which PV faces challenges as it is not attuned to the requirements of the assemblage. Somehow bridging across the deep-seated disconnections between different protagonists in the 'copro' set up hinged upon one particular individual, an *EIE* advisor who simultaneously sits in the *Mairie*'s citizens' advice bureau. However, as the energy advisor suggests above, the assemblage of the 'copro' set up, working through annual committee meetings, frequently obstructs those promoting PV in shared ownership buildings.

5.3.5 Regime impossibilities

In sum, regimes are the relations which come to bear upon efforts to innovate through 'locking out' novel technologies in a variety of ways. Table 5-2 provides a summary of the regime impossibilities generated by networked, scalar, place-based and urban assemblage relations discussed over the course of the chapter. While each spatiality generates its own impossibilities, they may also stand in mutually warranting and often reinforcing relationships to one another. For instance, through 'networks' it is possible to talk about the challenges facing small-scale PV systems in connecting to the grid – entangling relationships between incumbents, national policy and consumption practices that engender exclusions, subordinations, obstructions, and disconnections. However, networks that enact national and regional geographies of powering which are also (albeit differently) integrated through scalar relations. Scalar regimes involve competing claims over delimited spaces of authority – the borough, district, heritage sites and development zones – often through the formal channels of policy. Taking the shape of persistent national planning vetos, urban 'virtual envelopes' or planners disconnected from the imperatives of planning 'energetically', they frequently, but not exclusively, work in concert with a 'sense of place' that not necessarily institutionally but also often culturally and historically anchored into policy, practice and the popular imagination. Whether falling under the jurisdiction of state, region, city or locality, urban assemblages also involve 'lock out' through their sociomaterial rhythms – the renewal rate of the building stock, different energy requirements ownership and rental patterns.

What is enabled through working with a range of spatial metaphors is to understand regimes as variegated constellations that enact a range of 'impossibilities'. This material semiotic approach to regimes constitutes a rather different understanding of regimes from the prevailing *SNM*/*MLP* framework. Rather than presuming that network or territorial relations are the only relations that may generate 'barriers' to innovation, a material semiotic approach rejects presuming the precise shape and effects that regimes have upon efforts to innovate. While the *specific* relations entangled in regime spatialities are an empirical matter, a richer spatial imaginary assists in talking about how it is that particular solar spaces are 'locked out' on the basis of territories, jurisdictions, identities and rhythms – these are the particular spatialities that were identified in this study of innovation in urban PV; however arguably there could be others. While regime spatialities enact spaces of impossibility, innovation is a process with an important temporal element. Actors' utopics, while simultaneously revealing as well as formatively shaped by regimes (through the barriers they effect), are also transformative of the conditions of possibility. For instance, despite disconnected urban assemblages, London schools have in fact emerged as an important site for solar installations (see Section 6.6), most notably as a result *Solarcentury*'s synergy utopic (see Section 4.4.3). In Paris the *PLU* underwent reform in 2009 (see further Sections 5.4.1), owing a great deal to the Parisian Mayor's leadership utopic for purposes of carbon reduction (see section 4.4.1). And in Barcelona, *Fundación Tierra* has promoted a range of PV initiatives that circumvent the marginalisation of small-scale PV power (see Section 4.4.2). These changing conditions of possibility for solar in the city are the theme of the following section.

Table 5-2 Regime impossibilities

	Networked territories	Scales	Places	Urban Assemblages
Exclusion	Nation (France)	Urban (Paris)	Listed buildings+500 radius	Central urban areas (London) Schools
Subordination	Nation (UK; Spain)	Borough-urban (London)	Regeneration area	Social housing
Obstruction	Region (Catalonia)	Global-anywhere else	Planning permit areas	Shared ownership buildings
Disconnection	Nation (France)	National-global (Spain and UK) District-urban (Barcelona)	New developments	Shared ownership buildings

5.4 Solar temporalities

5.4.1 Progression and points of inflection

> you've got an important time dimension to what is happening… you'll probably find that things will have changed materially during your research period. And this is a measure of how dynamic the environment is!
> (Vice-president, *Solarbuzz*, Interview, London, November 2008)

Up to this point the chapter has taken a 'slice' through the empirical material which has focused on the causes and effects of barriers to actors' attempts to innovate. However, as this consultant knowledgeable of the PV industry accurately predicted, developments related to 'solar in the city' are fast-paced to an extent which at times eluded my efforts to keep up to date with events (see Section 3.4.4). The interviewee recounted that he had been involved with the PV industry for over 25 years, over the course of which he had seen "impressive evolutions" on the supply side taking place, such as in crystalline silicon-based PV modules "which have never stood still, with their cost coming down and their performance improving year by year!". This sort of progressive portrayal of developments in the PV industry is similarly displayed by Winfried Hoffman's (then president of *EPIA*) assessment of the PV industry coming into the 21st century:

> In the 1960s and 1970s the [PV] market developed on niche segments such as space solar cells. In the 1980s and 1990s several national R&D programmes… allowed some market development for off-grid and consumer appliances. Since the 2000s the PV sector has entered a 'transition phase' towards competitiveness in all market segments and in particular grid-connected applications.
> (Hoffman (2006) *Photovoltaics on the Way from a Few Lead Markets to a World Market*. **#G6**)

For Hoffman as well as numerous other commentators, from industry, policy and academic research the evolution of the PV industry can be characterised by a series of phases according to PV's gradually broadening application domains; from space to earth, from relatively small-scale remote, off-grid systems to utility scale solar power stations and smaller applications in the grid-connected built environment (e.g. Perlin 2000; Euractiv 2010, **#G4**). What is striking about Hoffman's periodization much more than different types of PV being assigned to particular decades of the last century is the progressive imaginary of Hoffman's compelling account. Significantly, Hoffman situates the (networked) obstruction in global silicon supply and the (scalar) dependence on national policy-driven demand as largely a thing of the past – nowadays, the industry is 'transitioning' towards competitiveness.

It certainly appears as though the conditions of possibility enacted by regimes do not sit still. In fact, progressive evolutions appear to be relatively common. For instance, French PV power generators are no longer excluded from the grid, as "nowadays, grid connection is much easier" in France (Energy Advisor 1, *IDEMU*, Interview, Paris, May 2009). In the UK, small-scale PV power has moved closer to being formally recognised as a future source of electricity through the coming into force of a feed-in tariff policy (as exist in France and Spain) in April 2010 which means that it is no longer overtly and entirely subordinated to larger scale electricity generation (DECC 2009). Nor are Barcelona's district Technical Services disconnected from PV technology anymore as "they know this topic of PV now, there's awareness and there's knowledge (Engineer 1, *Barcelona Energy Agency*, Interview, Barcelona, March 2009). And since autumn 2009 the Parisian *PLU* no longer obstructs those seeking to install PV, as solar panels have become redefined as legally allowed 'technical equipments' of buildings, which may exceed the virtual envelope.

While innovation is a dynamic process, the temporality of innovation has received perhaps even less systematic attention in the innovations literature than geography. References to time tend to be fleeting rather than systematic; for instance, *SNM*/*MLP* scholars Geels et al. (2008: 534), note that sustainable innovation may take "decades, rather than years". Overall, the literature has generated either historical studies characterized by periodizations or 'snapshot' moments of the state of affairs (e.g. Praetorius et al. 2010; Seyfang and Smith 2007; Smith 2010. Historical *MLP* studies tend to employ 'periodizations' according to calendar time, such as the "The Ongoing Energy Transition… of the Dutch Electricity System (1960-2004)" (Verbong and Geels 2007)). While scholars acknowledge that innovation is a 'non-linear' journey with 'twists and turns' (Schot and Geels 2008), the graphical representation of the *SNM*/*MLP* suggests otherwise. This does in fact seem to imply a rather linear understanding of innovation in which technologies moves from the 'local' level of the niche to the 'macro' landscape along the x-axis of a two dimensional graph (with the degree of 'structuration' serving as the y-axis – see Figure 2.1). This is related to the notion that with time, 'rules are thought to stabilise' and expectations about technologies to 'converge' (Geels et al. 2008). The problem with such an (however implicit) account of the temporality of innovation is that it projects a sense of progressive evolution when in fact developments may well also be regressive. For instance, in Spain government policy on the feed-in tariff is notoriously volatile, having undergone several reforms in the recent past. As the President of *Fundación Tierra* explains,

> Here, it's not as in Germany, where the [feed-in] tariff is a law, made by the legislator, and it's complicated to push through. Here it's a decree, which comes from the executive, so it's much easies to implement. But then, the president and the ministers go, and their replacements can just say, 'let's change this thing they did, this *Real Decreto*'. And since 1998 they've changed it four times, even though it's supposed to last for twenty-five years.
> (President, *Fundación Tierra*, Interview, Barcelona, March 2009)

It appears that the conditions of possibility certainly do not sit still, but neither do they necessarily move technologies smoothly along increasing degrees of 'stabilisation' and 'upscaling', as might be suggested by frameworks such as the *SNM*/*MLP*'s graphical representation. A greater sensitivity to temporality can be imputed to be at work in Späth and Rohracher (2010). The authors associate fast-paced and far-reaching energy sustainability-related transformation with particular leadership figures, in this case in the municipalities of Graz (Austrian) and Freiburg (Germany); and conversely diminished efforts with changes of municipal management. While thoughtfully drawing out the different experiences of Freiburg and Graz their treatment of the temporality as a topic in its own right remains peripheral, rather than centrally or explicitly interrogating what different timings mean for innovation more generally. Made more explicit, for Latour (1996: 88) the "timeframe of innovation depends on the geometry of the actors, not on the calendar". In other words, for Latour the temporality of innovation is, like space, an emergent feature. Such an understanding of time is similarly developed by sociologist Adams (1994) Adams proposes that time, rather than an abstract concept, is framed through different social groups' and institutional practices. Acknowledging time as a feature that is emergent from social and materially heterogeneous interactions makes it possible to distinguish the progressive 'evolution' explored towards the beginning of this section from a second form of temporality, that of 'inflection', suggested by cases such as the Spanish *Real Decreto* and Späth and Rohracher's analysis of sustainability policy and leadership change. The 'twists and turns' of innovation are particularly evident particularly with national policy change which may occur as (or even more) frequently as governments come and go. However, other points of inflection can be distinguished as playing out across the heterogeneous barriers and regimes spatialities identified over the course of this chapter, which are not purely regressive.

The concerted reform of the Parisian *PLU* in late 2009 is one example. This effectively made the spatial development document compatible with the city's more recent *Plan Climat*. This effectively created the conditions for allowing solar panels (as well as other 'sustainable development technologies') to be installed in the city. No longer excluded from Paris' rooftops, this was done by reclassifying solar panels (both thermal and PV) as 'technical equipments', making them legally equivalent to lifts and other elements considered as functionally necessary (and therefore 'allowed') building components, which are exempt from the 'virtual envelope' policy. Perhaps the paradigmatic case of a point of inflection in innovation in PV is embodied in the notion of 'grid parity'. While a debated concept in the industry, grid parity can – loosely – be taken to refer to the point in time at which the cost of one unit of solar power is equal (and becoming cheaper) than conventional grid electricity. The imaginary is seductive – in the UK, *Ernst and Young*'s (2011: 4) 'UK solar PV industry outlook' report stated that "[g]rid parity with [electricity] retail prices is expected to be achieved in the UK by 2020 without subsidy for non-domestic, on-site installations". For a country that, it has been argued, is "one decade behind… compared to the leading countries on the European market" this constitutes a seminal point of inflection, of "An Island awakening" (S&WE 2010a: 164).

While such moments in time constitute points of reference, and to a greater or lesser degree signal substantial shifts in the conditions of possibility, they need to be understood as standing in an intimate relation to the work that takes place 'behind the scenes'. The sense of impending grid parity should not mask the fact that the industry has existed for decades and has largely relied on national governments to artificially push up demand for the technology. On the other hand, the *PLU* reform took not only a lot of time but also a "quite some *réunions* 'up there'" (Energy Advisor, *PASU*, Interview, Paris, May 2009), i.e. at the high echelons of Parisian and national governments; inclusive of efforts to engage the *ABF*s in the process (see Section 6.3). In the UK, government introduced a feed-in tariff analogous to that in place in numerous other European Member states to encourage non-utility scale low carbon electricity generation. While largely a latecomer in terms of state-supported market development tools, since coming into force in April 2010 it has been associated with an over four-fold increase in the nationally installed PV capacity up to mid-2011 (OFGEM 2011). In the context of an existing state policy (the RO) which subordinates technologies such as PV to large scale renewable generation its very existence marks a step change in government attitudes towards solar (and other small-scale) power. Importantly, it was hard fought for by the small and gradually consolidating UK PV industry. While April 2010 thus marked a point of inflection, neither policy reform, nor grid parity simply materialise. The absence of points of inflections, whether marking progression or regression, suggests that barriers may be experienced as persistent when evolutions are not encountered as such.

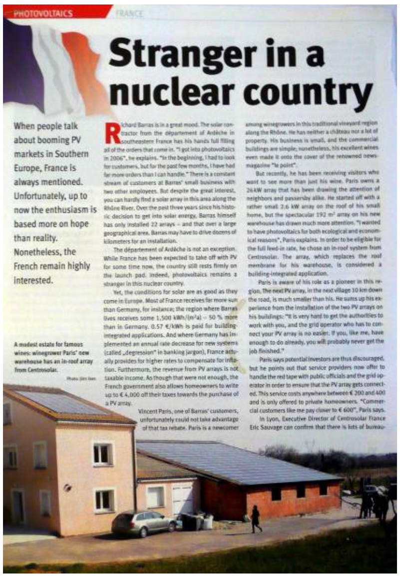
5.4.2 Persistence

Section 5.3.4 stated that implementing PV in Barcelona in new developments remains a rather limited undertaking considering the densely built up nature of the city. Besides a matter of disconnections from urban assemblages, in Barcelona implementing urban PV remains, for the vast majority of prospective small-scale generators, a perplexing endeavour owing to the obstructions created by a rather convoluted administrative set up at the national scale. The *Real Decreto* framework requires individual generators to keep a record of all magnitudes of electricity generated, to fill out a tri-annual tax return (even though the power produced is taxed at zero percent, non-compliance faces a financial penalty) and to issue monthly bills to the utility. The amount of paperwork involved with accessing the national feed-in tariff under the *Real Decreto* were described as “such a dealbreaker” (Energy Advisor, *Ecoserveis*, Interview, Barcelona, March 2009) by an interviewee from a local energy non-profit. Upon being asked whether this set up was likely to change, the President of *Fundación Tierra* simply stated, “no, not for now”. Similar to the persistence of such obstructions in the networks of electricity power in Spain, the French case constitutes a case in which initial exclusions are nowadays experienced as somewhat milder forms of obstruction. The illegality of PV was inflected with the coming into force of the first (then-modest) feed-in tariff in 2001 which formally secured the technology’s legality (the Director of *CLER* explained, “the first tariff was as if to say, ‘ok, photovoltaics has the right to exist. But we won’t *really* encourage it’”). However, the legacies of the traditionally monopolistic model continue to pervade the current situation. To this day, obtaining grid-connection is a notoriously drawn-out and costly process. The “bureaucratic red tape” that means that grid connection takes 39 weeks on average (compared to approx. 6 weeks in Germany) at costs ranging between 200 and 600 Euros (S&WE 2010b) is testament to the enduring influence of the national utility, *EDF*. Headlines as late as 2008 and 2009 in the renewable industry magazine *Sun&Wind Energy*, describe the French national grid as “EDF’s realm of shadows” (S&WE 2008) and PV as a “Stranger in a Nuclear country” (S&WE 2009) (see Figure 2).

In Paris itself, the reform of the *PLU* was a significant step towards enabling PV in Paris, however, it had not the effect of streamlining planning permissions for the technology as desired by reformists. While the normal procedure for installing solar panels now is to file a 'works declaration' (*déclaration préalable*) with the municipality (which is usually tacitly given within a period of one month), *patrimoine* sites remain beyond the jurisdiction of the municipality proper. The *ABF*s jurisdiction over a large part of the Parisian built environment persists as a substantial factor affecting efforts to implement PV; albeit one that is nonetheless limited to instances of 'co-visibility'[60]. Thus, while the alterations to the *PLU* relevant for solar panels state that the intention is to 'encourage' the use of 'sustainable' technologies (including solar panels, wind turbines, green roofs, and insulation), the reformed document also states, "providing they are *harmoniously* integrated into the neighbouring built environment"[61] (Mairie de Paris 2009: 19; emphasis added). This indicates that whether the Mayor's aspirations of Paris becoming a 'solar city' are met, strongly hinges upon how 'harmonious integration' is interpreted by the *ABF*s.

The above cases of persistence alert of the possibility that heterogeneous barriers operating across different spatial relations may inflect at different times. This is certainly the case with obstructions persisting in French electricity while formal exclusions have been resolved; conversely in Paris itself obstruction (in the shape of the *PLU*) has largely been resolved, while the subordination of PV to *patrimoine* persists across scalar relations. The implication is that it should not be taken for granted that technologies can simply 'break through' once and for all. This is a popular account in the literature: it is thought that novel technologies may 'grow' and into regimes of their own, at which point they have formally 'broken through'[62]. The problem with such an (however implicit) spatially homogeneous account of the temporality of innovation is that it risks focusing attention on a singular end point towards which innovative efforts gravitate, disregardful of the potential diversity of meanings that 'breaking through' may have, for a diversity of innovators (see Section 4.2).

[60] Conversely if there is no 'co-visibility', the ABFs' decision is not binding – however, as experts, the ABFs' advice is weighty and delays are common when it is not obeyed.
[61] "…Ces dispositifs sont autorisés en saillie des toitures pour les bâtiments existants, en saillie du couronnement du gabarit-enveloppe pour les constructions neuves, sous condition d'une insertion harmonieuse dans le cadre bâti environnant."
[62] This is thought to occur in the context of 'landscape pressures' and regimes 'incoherences'.



PHOTOVOLTAICS FRANCE

Stranger in a nuclear country

When people talk about booming PV markets in Southern Europe, France is always mentioned. Unfortunately, up to now the enthusiasm is based more on hope than reality. Nonetheless, the French remain highly interested.

PHOTOVOLTAICS

EDF's realm of shadows

PHOTOVOLTAICS PV LEGAL

Six weeks in Germany, 39 in France

Why is there not already far more solar power in sunny countries? When this question is raised, people like to point to bureaucracy. And rightly so, as a survey of companies conducted by PV Legal has shown. PV Legal is an initiative launched by European solar energy associations and the consulting company Eclareon. It pursues the aim of removing administrative barriers against the installation of PV systems.

1 2 3

Figure 5.4 Persistent barriers in French electricity

(Source: [1]S&WE 2008; [2]S&WE 2010b [3]Geels et al. 2008)

5.5 Conclusion: variations in solar im-/possibility

Cost is the main barrier and it's a financial problem… If it was cost effective, then everyone would be doing it.

(Managing Director, *Carbon Descent*, Interview, London, November 2008)

Cost is not the problem! You go to a bank and they'll finance it… and with the feed-in tariffs the loan pays itself back.

(Activist-academic, Interview, Barcelona, March 2009)

Why not install PV … there's an interesting feed-in tariff for solar electricity. It's six times higher than the retail price of electricity… it's even financially lucrative.

(Energy Advisor 1, *IDEMU*, Interview, Paris, May 2009)

at what point a grid parity argument would make sense in London and Paris is a long way off because they're so far north. But if you are looking at Barcelona or major cities further south in Spain, then that that's within a five year time horizon might be an applicable argument.

(Vice-president, *Solarbuzz*, Interview, London, November 2008)

Why is the delivery of PV a ‘financial problem’ in London in 2009, while only a few months later it appears as viable and even potentially profitable in Barcelona and Paris? The multiplicity of experiences captured by the quotations above alerts to the fact that ‘barriers’ are certainly not universal and homogeneous across time and space. Time, just like geography, ‘matters’ in shaping the conditions of possibility for urban PV in Barcelona, London and Paris – and anywhere else. But, financially unviable, a technology that ‘pays itself back’, or a ‘lucrative investment? This example serves to illustrate that what constitutes a barrier in one setting may not be a universal feature affecting actors’ experiences of innovation in the same way elsewhere, at all times. PV’s status as a potentially ‘expensive’ technology, frequently cited as perhaps the most pervasive ‘barrier’ to PV’s wider uptake (e.g. Verbong, Geels et al. 2008; Faiers and Neame 2006; Verbong and Geels 2007), depends on range of factors. While a higher radiation budget may imply that grid parity is closer on the horizon, expected technology cost reductions, future retail prices of electricity, manufacturing processes, supply chains and ‘bank loans’ and ‘feed-in tariffs’ are all features that shape PV’s cost equation. Most basically, this suggests that locating the ‘barriers’ to innovation in the ‘intrinsic’ attributes of a technology is fundamentally misplaced. More expansively, understanding barriers facing novelty – whether relating to, for instance, the ‘right price’, aesthetical ‘look’ or ‘green’ credentials – requires a careful engagement with the prevailing conditions of what is in place. Accordingly, features such as the ‘lock out’ of new technologies must be traced as effects of variegated spatial constellations, ‘in action’ in order to avoid essentialising particular actors or spaces as necessarily inhibiting innovation.

The merits of a material semiotic analysis emerges strongly when applied to explaining variations of unfolding solar im/possibilities. By way of a summary the chapter’s analysis, Table 5-2 captures differences that emerge between Barcelona, London and Paris in terms of the heterogeneity of ‘lock out’, regime spatialities and solar temporalities. For instance, it makes it possible to see that efforts to implement *any PV* in Barcelona, London and Paris are significantly shaped by the networked and scalar character of the industry and the global/industry-national/policy dynamic, respectively. Focusing on urban contexts specifically reveals that in Barcelona PV on public buildings has progressively improved through district architects’ evolving skills; however that a range of urban PVs are persistently ‘locked out’ in particular owing to the slow renewal of the city’s dense central areas and continued administrative obstructions in becoming eligible to the feed-in tariff. In London, income-rewarded urban PVs, those on public buildings, in schools and priority development sites (such as covered by the Mayoral planning policy) have become reality, despite the fact that in the latter it is still the case that other technologies are chosen above PV, even in central areas where the technology is increasingly used alongside other technologies such as CHP. In Paris formerly excluded grid-connected systems and subordinated urban development zones have become possible, as energy- and climate considerations are lessening the municipality's, energy consumers', and importantly, the *ABF*s' disconnections to concerns with energy. However, persistent barriers remain in terms of allowing new technologies in planning permit sites and getting shared ownership housing committees to reach common decisions quicker. In addition, social housing blocks remain largely off bounds for PV and grid connections remain obstructed by long delays.

On the whole, rather than understanding urban PV as a bounded 'niche' which travels along a curve of increasing 'structuration' over time, the chapter argues in favour of a more nuanced understanding how time and space matter for innovation. The fundamental departure of a material semiotic account of regimes is to question how precisely 'barriers' to innovation are 'locking out' novelty, what relations produce them and what, as a consequence, they signify in terms of prospects for change. 'Lock out' is the heterogeneous product of spatial regimes which may preclude the formation of novel solar spaces by constituting the relations through which exclusions, subordinations, obstruction and disconnections are effected. However, while regime relations work to 'lock out' novelty in heterogeneous ways but they do not do so once and for all. By treating the quality, spatiality, and temporality of regimes as features that are emergent from innovation in practice, a material semiotic take on barriers enables one to explore how the spatial and temporal conditions of possibility for innovation are not universal and homogeneous and certainly do not 'sit still'. The starting point of the analysis was that in the absence of utopics – those activities which seek to gather alternate states of affairs – 'nothing' is intelligible in terms regimes of innovation. The normalcy of the conditions of possibility contained in regime relations becomes knowable and amenable to analysis as innovators grapple with a range of barriers across the regimes that effect them, potentially transforming the prevailing conditions of possibility. It is with the changes in the conditions of possibility that the following chapter is concerned in more detail. While at present the concern was with exploring the 'texture' of constraint and prospects for change, the next chapter explores several instances of particular actors' utopics with respect to the role PV plays in processes of ‘sustainable’ transformation. The chapter is concerned with the relational making of a solar city, which, it is proposed consists of a series of ‘solar heterotopia’ – sites of otherness from the ‘mainstream’ which are however partial, imperfect and impure versions of the original intention.

Table 5-3 Heterogeneity, spatiality and temporality of ‘locked out’ solar possibilities

‘Locked out’ urban PVs	Barcelona	London	Paris
Persistence	Income-rewarded[2] **Central areas[4]** *Small grid-connected[1]*	Planning permit sites[2]	*Small grid-connected[1,2]* **Planning permit sites[2]** Social housing[4] *Shared ownership buildings[4]*
Progression	*Any PV[1,2]* **Public buildings[2]**	*Any PV[1,2]* **Central areas[4]**	*Any PV[1,2]* Planning permit sites[2] Priority development sites[3] Shared ownership buildings[4]
Inflection		Income-rewarded[2] Public buildings[2] Priority development sites[3] **Schools[4]**	Priority development sites[3] **Small grid-connected[1,]**

Legend: **Excluded,** Subordinated, *Obstructed,* Disconnected; [1]Networks, [2]Scales, [3]Places, [4]Urban Assemblages

6 Solarising the city

6.1 Introduction

A central driver behind academic, public policy, and societal interest in renewable energy technologies such as PV derives from their promise for more 'sustainable', that is more ecologically benign, futures. This has been theorised in the innovation studies literature through considering how such technologies are generative of 'sustainability transitions' (e.g. Smith et al. 2010; Grin et al. 2010). Such far-reaching transformations in the systems of social and technical practice (Smith 2007) are thought necessary for avoiding the catastrophic consequences associated with climate change. While it has been argued that the prevailing framework of 'Strategic Niche Management' and the 'Multi-level Perspective' (*SNM*/*MLP*) provides a powerful tool for understanding the complexity involved in sustainability transitions, Chapter 2 (Section 2.2.4 questioned this assessment in three related ways. First, it was questioned whether the model's spatially and temporally smooth imaginary of interacting 'niches' and 'regimes' has purchase for evidencing *unfolding* transformations, as opposed to narrating transitions in the past (such as a 'hygienic transition' (Geels 2005a)). Second, it was argued that the model lacks scope for understanding the role that technologies themselves have in generating transformations (based on the relational work they perform as 'techniques'). Closely related to this point, third, the model's implicit assumption that technologies transform purely through being somehow more 'sustainable' than existing technologies was cast as fundamentally failing to account for the highly political nature of innovating using technology.

This chapter conducts a material semiotic analysis of the transformative impact of urban PV in Barcelona, London and Paris, which addresses these three shortcomings of the *SNM*/*MLP* identified in Chapter 2. Significantly, it rejects concluding, as Verbong et al. (2008) have (in the Netherlands, in their case), that PV has 'failed' to impact as it has not 'broken through' as a mainstream way of generating electricity. Instead, it is argued that PV is implicated in unsettling, dis- and re-ordering existing relationships around energy in several 'sustainable' ways. However, Section 6.2 begins by cautioning against taking for granted a particular notion of the sort of sustainable transformation that PV is implicated in. Sensitivity is raised to understanding the 'sustainable' attribute as something that acquires significance through PV's relational work as an utopical technique (Chapter 4), rather than its intrinsic attribute of being somehow 'greener' than more established technologies. The chapter then proceeds with exploring four 'solar heterotopia', sites of otherness, which emerge as the conditions of possibility are being reconfigured through the interplay of actors' innovative utopics and regimes, the relations that are in place (Chapter 5). In this way the chapter takes as its chief focus the interplay between different actors' attempts to spatialise different notions of the desirable, 'sustainable' future in the face of forces which sustain and reproduce the status quo. While understanding *sustainability icons*, the *resource city*, *sites of prosumption* and *solar schools* as somehow alternate from a 'mainstream' the chapter cast these as partial, imperfect and impure 'sites of otherness' in which a diversity of sustainability politics diffract. In this way, the notion of heterotopia deployed in this chapter enables a much more nuanced account of PV's transformative impact than is possible through an *SNM*/*MLP* framework.

6.2 Un-black-boxing unsustainabilities

> …because there's one thing that's certain with PV. What it gives you, is what you effectively don't know, which are the kilowatts that you consume. Electrons are invisible! Solar, it gives you a way of knowing. It's a metric that up to now just hasn't been available. (President, *Fundación Tierra*, Interview, Barcelona, March 2009)

The central contention of this section is that PV is a technology which surfaces otherwise invisible relationships and makes it possible to offer these up for re-interpretation. In science and technology literatures, the questioning of previously taken for granted relationships is captured by the notion of 'un-black-boxing', where the 'black box' (Callon and Latour 1981: 285) itself describes the states of affairs which are normally unquestioned. For the President of Barcelona-based non-profit *Fundación Tierra* PV brings into focus one's electricity behaviours through providing a quantitative 'metric' of the electrons consumed – this is precisely what makes PV such a powerful technology for 'eco-empowerment' (see Chapter 4.2). For the President of *Fundación Tierra*, PV installations act as mediators that assist in approximating the environmental impact of energy consumption. They do so by being interposed between the individual or the household and the energy utility, on the one hand, and the environment, on the other. This, Miralles explained, is a promising basis from which a more ecologically and socially just energy future might take shape. This is provided, of course, that the PV installation is connected to display monitors which exhibit the relevant information in a format that is accessible and digestible for the (often lay) electricity user. As a technique, Chapter 4 noted, urban PV does not end at the panel; as illustrated by the way in which the 'solar totem' in London's Bishop Square conveys a myriad of complex physical and engineering and concepts to the passersby in Spitalfields:

> The core idea of the display is simple: … The main animation shows a constant 'rainfall' of energy that relates to the amount of power being generated from minute to minute. A sunny day brings a torrential downpour of energy, a winter's evening will produce a light shower.
> (More Associates 2008, *Bishops Square (Solar Totem)*, **#L154**)

Through, in this case, visualising electrons (or verbally translating these into 'cups of tea', see Figure 5.1), urban PVs such as the solar totem are fundamentally implicated in surfacing otherwise invisible relationships around electricity. Such un-black-boxing may have far-reaching effects, as a range of academic literatures indicate. For Star, the "invisible quality of working infrastructure becomes visible when it breaks: the server is down, the bridge washes out, there is a power blackout" (Star 1999: 382). Power cuts are perhaps the paradigmatic case of un-black-boxing, or at least one which has received substantial attention (Graham and Marvin 2001; Bennett 2005). Bennett (2005: 448), for instance, notes how the August 2003 blackout in the US and Canada brought into focus electricity grid as "a volatile mix of coal, sweat, electromagnetic fields, computer programs, electron streams, profit motives, heat, lifestyles… — to name just some". Large systems such as electricity work best when they go unnoticed (Perry 1995). While black boxes thus obscure the relationships that produce them, processes of un-black-boxing are revealing of the otherwise invisible "modes of thought, habits, forces and objects" (Callon and Latour 1981: 285) that underpin the stability of existing relations. However, in contrast to conventional power cuts which may persist for the fraction of a second to several days, as with the 2003 North American blackout, there are cases of un-black-boxing where streamlined relationships cannot be seamlessly patched up as the failures that have become exposed are too fundamental.

"Most of the time, this is what the display shows. Live data showing power production scrolls across the display at moderate intervals. Every 8 minutes or so, the display cuts to an informative animation telling a simple story about energy use - how the generated power relates to cups of tea, digital cameras, and laptop computers for example. Information is also presented in standard units like Kilowatt hours for those lucky people who understand them."

Figure 6.1 Un-black-boxing electrons

(Source: More Associates 2008, Bishops Square (Solar Totem). **#L154**)

A prime example is that of the 'unsustainability' of fossil fuel-based power generation. As the first pages of chapters 'power down' and 'power up' from the *Centre for Alternative Technology's* 'Zero Carbon Britain' report[63] illustrate, 'renewable' energy technologies such as PV perform a fundamental distinction between conventional energy sourcing and renewable generation. The juxtaposition of photography and text illustrates how the environmental quality of renewable energy makes it possible to declare that the "…age of oil is over" (a statement visually juxtaposed with a worn oil pump handle at a service station). Instead, "someday we will harness the rise and fall of the tides and imprison the rays of the sun" (caption to the image of the blade of a wind turbine against a blue sky) (CAT 2007: 49; 82). In the broader context of the report, text and image serve to perform a fundamental tension between the resource intensity and negative externalities of fossil fuel based energy systems and the promise of clean, carbon free energy in the future.

[63] It should be noted that the report includes nuclear power in the selection of 'power up' technologies, however argues against such a 'brittle' form of power generation.

While UK grid electricity is particularly carbon intensive, even nuclear power, which dominates electricity supply in France (at 78 percent nuclear) and is often portrayed as ‘low carbon’, becomes unsustainable in juxtaposition with technologies such as PV – “there’s nuclear waste and we don’t know what to do with that” (Energy Advisor, *PASU*, Interview, Paris, May 2009). Here the alternative possibilities that are latent in technologies such as PV effectively un-black-box existing states of affairs through effecting shifts in meanings associated to otherwise taken for granted electricity infrastructures.

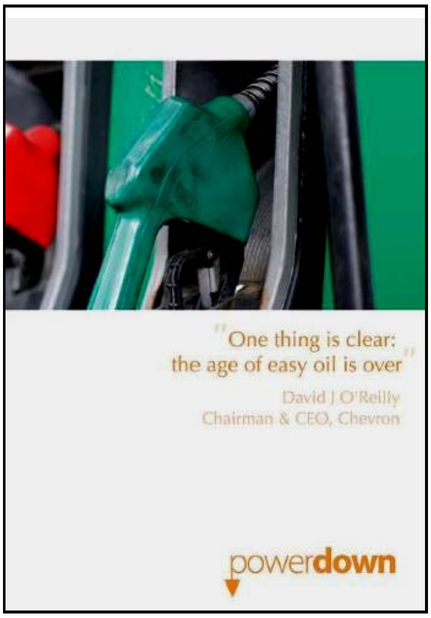
However, it is here proposed that the particular ‘unsustainabilities’ that become exposed should be interrogated, rather than taken for granted. In practice, unsustainabilities may be numerous, distinct as well as overlapping. This is illustrated by a Barcelona-based energy agency interviewee, who over the course of just a few sentences entangles a range of energy relationships into a ‘seamless web’ (Hughes 1986) of ‘unsustainability’:

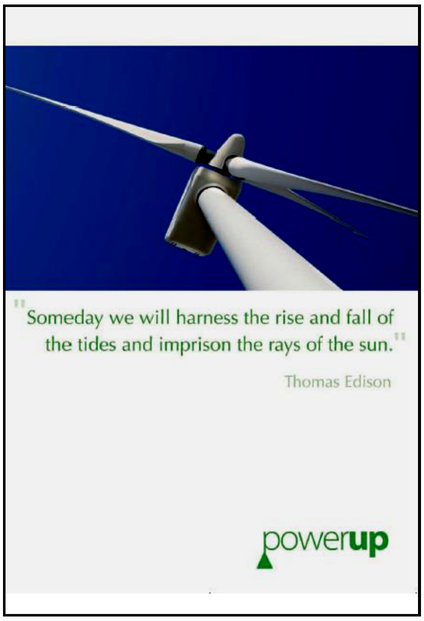
> We’re talking about replacing the fossil fuel-based part of our electricity with the most renewable possible, but this doesn’t change the fact that we need an ‘energy’ culture just like we need the sun. Energy culture! By whatever means, but we need it a lot especially in construction. What’s happening is that in the last five years lots of people have installed air con and there are more household electronics plugged in then ever, transformers, mobile phone chargers, halogen lighting, computers, DVD players, playstations [pauses, side-glances to his colleague, laughs guiltily] it’s all out of control.
> (Engineer 2, *Barcelona Energy Agency*, Interview, Barcelona, March 2009)

Unsustainable production, construction, consumption – this is to show that in practice it mostly the case that terms such as ‘sustainability’ and ‘energy culture’ are frequently not systematically reflected upon; at least not by the vast majority of participants in the research. They may relate to matters of resource quality, efficiency, consumption or construction – however, there could be others, arguably, such as the socially ‘unsustainable’ asymmetric client-relationship between utility and citizens that is central to notions of eco-empowerment (see 4.2.1). Crucially, what different notions of the ‘sustainable’ share in common is that they are relationally constituted as alternatives to what is performed as the ‘status quo’. It is the very possibility of the sorts of configurations provided by technologies such as PV that makes it possible to conceive of more 'sustainable' relationships – whatever these are thought to be specifically. In other words, rather than existing 'out there', as in the 'landscape pressures' of the *SNM*/*MLP* framework, un/sustainability is a relationally intelligible effect, something that becomes meaningful as a tension in existing systems through the relational imaginary of more sustainable alternatives. As such, if un-black-boxing works through 'othering' the unsustainabilities of existing relationships, then evidencing 'sustainable transformation must be attuned to technologies' relational juxtaposition to existing configurations.

Taking into consideration the relational constitution of normative notions such as 'sustainability' provides an entry point into understanding the 'sustainable' transformative impacts that PV technology might be having in Barcelona, London and Paris. This can be explored through focusing on a number of urban spaces – heterotopia – that come into being at the intersection of different actors' attempts to convert (whichever notion of) the sustainable 'good' into practice. In this way, the chapter's discussion constitutes an important departure from *SNM*/*MLP*'s understanding of new 'sustainability spaces' (i.e. niches) as sheltered sites that are somehow outside of the mainstream. A heterotopia is "a gap that is betwixt and between… a space of disintegration, of combination… and disorder" (Hetherington 1997: 139-140). As such, heterotopia are not (necessarily or even predominantly) located on the margins of existing relations. Rather, they are relational sites – 'in between' spaces of alternatives. While, like niches, it may be the case that actors attempt to orchestrate sustainability, the resulting outcomes are inherently spaces of contingency, uncertainty and 'drift': "they deviate from their planned purpose for a variety of reasons often outside anyone's influence" (Ciborra and Hanseth 2000: 4). As such, 'sustainability' outcomes are heterotopic in nature; they are imperfect and partial realities that emerge as numerous actors' diverging and potentially conflicting innovative utopics intersect with one another, as well as with that which is already in place.

The remainder of the chapter now turns to exploring four different 'sites of otherness' in which the unsustainabilities of the status quo are being exposed, negotiated, contested and – to some extent – reconfigured.





"One thing is clear: the age of oil is over… someday we will harness the rise and fall of the tides and imprison the rays of the sun."

Figure 6.2 'Zero Carbon Britain'
(Source: Delanoë 2007)

6.3 Sustainability icons

> On Barcelona's Forum Esplanade promenade stands a large, sculptural solar array, which with a surface area of 10,500 m² is Europe's largest. […] The solar array on Forum Esplanade is the city's sustainable landmark, creating a distinctive cityscape along the beach promenade.
> (Sustainable Cities.dk, *Barcelona: Leader in Solar Energy*. **#B130**)

Towering over the mouth of the River Besos in Barcelona, the urban PV power station at the 'Forum of the Cultures' provides an arresting sight (see Figure 6.4). Along with its sister shading structure in the Forum Area it offsets about 440 tons of CO2 every year and has the capacity to power 1000 homes (Agència d'Energia de Barcelona 2007. **#B3**). The Forum 2004 'pergola' is one of the most iconic urban PV installations of the recent past (at least in Europe and perhaps beyond). Its installation coincided with the 'Universal Forum of Cultures' (*Fòrum Universal de les Cultures*), an international cultural event taking place in Barcelona between May and September

2004. While it is located on the fringes of central Barcelona, the Forum 2004 area's slogan is bearer of the *Ajuntament*'s message of change: 'the future is now' (El Fòrum 2004: el futur ja és present; Agència d'Energia de Barcelona 2003. **#B3**). Akin to the iconic positioning of the Forum 2004 pergola, across London and Paris similar a number of PV installations of such iconic character are beginning to pepper the urban landscape. The sky-high 'fork' structure crowning London's Vauxhall bus interchanger is another case of monumental urban structures covered with solar panels. According to *Solarcentury*'s brochure, as a "landmark solar scheme… Vauxhall Cross reaches out to the sun, generating 30% of the energy required to power the 24-hour bus station area" (Solarcentury 2007; **#L184**). The PV installation at London's City Hall is another urban icon through which sustainable ideals are converted into actual urban space. As its high profile architects, *Foster+Partners*, argue, with its PV panels City Hall "expresses the transparency and accessibility of the democratic process and demonstrates the potential for a sustainable, virtually non-polluting public building" http://www.fosterandpartners.com/. **#L50**). These iconic PV systems appear as a "symbolic for sustainable building culture" (SCHOTT Solutions 2009. **#B128**), as architects Zuniga and Horvatitsch conclude about the Forum 2004 pergola; and are frequently positioned as monumental achievements considering the difficulties of delivering PV in the city. As such they can be taken as part of a 'leadership' innovative utopics' identified in 4.4.1, taking place in the context of existing regime spatialities. While some of these urban 'sustainability icons' have been mentioned in previous chapters, little was said about the importance of such spaces in terms of the broader sustainability impacts they may have. Understanding such PV installations, as the above, as heterotopia, makes it possible to consider how they constitute important sites through which broader debates about urban future take place. Here it is argued that they are sites in which entrenched boundaries and black-boxed relations are opened up for examination and reconfiguration, such that the new political imperatives they embody come to stand in strong contrast with existing and established urban development patterns. In Paris, for instance, two notable PV installations stand out in a similar manner to the Forum 2004 pergola and the installation at City Hall. Against the backdrop of a regular Parisian landscape, the high profile regeneration project in the 18th *arrondissement* (the ZAC Pajol) is positioned by the Mayor in an electoral manifesto as an example of "acting locally, for the planet" (see Figure 6.3). It is one of several installations that are thought to make Paris a 'solar capital'. Even Paris' foremost urban icon, the Eiffel Tower, is rumoured to be kitted out with solar panels in the not too distant future (see Figure 6.3). The article that appeared in one of France's free commuter papers states that – at the time of research – a study was being conducted about the possibility of embedding PV panels into the first level and nearby commercial stands. Sustainable ambitions, according to *20 minutes* is such that the "iron lady" herself *wants* to be doused in "glittering solar finery" (20 minutes.fr 2009. **#P1**).


actualités générales

La Tour Eiffel veut des panneaux solaires

1


ENVIRONNEMENT

Agir localement, pour la planète

Face à la menace planétaire que représente le réchauffement climatique, il faut agir. C'est pourquoi depuis 2001, toute l'action municipale a été fondée sur l'impératif du développement durable, qu'il s'agisse des déplacements, des crèches et des logements sociaux réalisés en haute qualité environnementale (HQE), ou de la consommation d'électricité dont la part destinée à l'éclairage public a diminué de 80 %. Déjà, **de véritables écoquartiers naissent à Paris**, comme aux Batignolles, à Rungis, Boucicault ou Claude-Bernard.

Le **Plan Climat** que le Conseil de Paris a adopté en octobre 2007 fixe des objectifs particulièrement ambitieux : ainsi, pour la prochaine mandature, nous proposons de **réduire de 15 % l'ensemble des émissions de gaz à effet de serre (CO2) produites à Paris**.

Pour tous les programmes d'aménagement nouveaux, nous tendrons vers l'objectif d'un bilan énergétique neutre **(zéro émission de gaz à effet de serre)**, voire positif. Un grand **plan de réhabilitation des 171000 logements sociaux**, sera engagé, visant l'objectif d'une réduction de 30 % des consommations énergétiques en 2020.

Paris, capitale mondiale de l'énergie solaire! La Ville engagera (comme ici à la Halle Pajol, 18e) un vaste plan d'installation de 200 000 m² de panneaux solaires d'ici 2014.

2

Figure 6.3 Parisian Urban icons: ZAC Pajol and Eiffel Tower

(Source: [1]20 minutes.fr 2009. **#P1**; [2]Ajuntament de Barcelona and AEB 2007. **#P30**)

However, urban icons are by no means necessarily uncontested sites. While in Paris little evidence was found at the time of research about repercussions to Mayoral ambitions[64], the municipal sustainability ambitions of the *Ajuntament de Barcelona* and the *Greater London Authority* that are enacted in and through urban icons result not in perfect spaces of sustainability, but solar heterotopia. These take shape around these high profile urban icons, at the confluence of contra-indicating interpretations and aspirations, but their repercussions are felt far beyond the physical boundaries of the Forum 2004 Pergola and City Hall.

For instance, while the *Ajuntament* positions the Forum 2004 pergola as part of Barcelona's new ecologically friendly urban 'energy culture' (Ajuntament de Barcelona 2003a), there are others for whom "the sculpture is a monster" (Josep Puig, Intellectual and Activist, Interview Barcelona March 2009). Despite the merit of sustainability projects and leadership initiatives in general, for activist-academic Josep 'Pep' Puig the installation embodies the *Ajuntament*'s political orientation

[64] Owing to the recent nature of developments, rather than the uncontested nature of change.

towards 'the outside', as marketing Barcelona as a particular 'brand' of sustainable city. And Pep Puig is not alone in his critical stance towards municipal 'sustainability' policy. Powerfully juxtaposed in Figure 6.4 is a very tangible way in which the Forum 2004 site served as a physical and discursive space of the pergola became a heterotopic site in which divergent understandings of, and commitments to, sustainability were contested. The bottom newspaper cutting was published in 2004, at the time of the *Ajuntament*'s 'Universal Forum of Cultures' event. It shows protestors arriving by sea against the background of the 2004 Pergola, reclaiming the Forum 2004 space as a 'peoples' space', as the event intended it, through this "seaborne invasion". They were positioning themselves against what was seen as an orchestration of 'sustainability', that masked the event's business orientation, the dubious reputation of the event sponsors and speakers[65], and the fact, interpreted as hypocrisy, that the event organizers did not condemn the 2003 invasion of Iraq[66]. The image of the protestors contrasts starkly with the second image that positions Barcelona as a "leader in solar energy".

Rather than an icon of sustainability, for Pep Puig and others the pergola is emblematic of municipal unilateralism, imperviousness, and even arrogance. The President of *Fundación Tierra* is himself particularly concerned with the effects of the municipality's operations in the way it effects upon his aspirations for eco-empowerment (see 4.2.1). He sees the *Ajuntament* as more concerned with being '*seen* to be green' through positioning Barcelona as in competition to outperform other cities in international urban emission rankings (an opinion backed up by the *Ajuntament*'s concern with not falling behind in 'carbon emission reductions 'rankings' (London SE1 2004). He further explained that the *Ajuntament*'s activities as fundamentally failing to broaden participation to the benefits of solar energy, in favour of just unilaterally 'doing it themselves', for political ends:

> We always had a resolute commitment to promoting PV in urban environments. And in parallel, you had the *Ajuntamento*, doing their own installations on public buildings… We've always argued that this is not the best way to do it, to make solar available to more people… We designed the *Ola Solar*… and we proposed ourselves [for managing further

[65] Including companies such as Nestle (with questionable trade practices in the developing world); speakers such as a former President of Bolivia who was involved in the suppression of protestors against a highly polluting Potosi mine in Bolivia.
[66] Put down several sponsors of the event having stakes in the arms industry.

participatory projects]… but they wouldn't let us. It was too complicated, because if you're the *Ayuntamiento*, and you just want to do it, then you do without the hassle of negotiating with an NGO…
(President, *Fundación Tierra*, Interview, Barcelona, March 2009)

1

2

Figure 6.4 Sustainability landmark or 'monster'?
(Sources: [1]Sustainable Cities.dk, *Barcelona: Leader in Solar Energy*. **#B130**; El Periódico 2004, *Altercado en la sede de la ciudad cultural - la jornada*. **#B60**)

Here it becomes very clear that the sustainability versions of the *Fundación* and the *Ajuntament* are not readily compatible in the sense that they are not based on converging visions of what a sustainable city might look like. To use the terminology of Chapter 4, the sustainability leadership, a form of innovative utopics that works through the exemplary promotion of showcases plays out rather differently across the Fundacion's aspirations for eco-empowerment and the Ajuntament's engagement of PV as a utopical technique for carbon reduction. While sharing elements in common, the relations that each seek to reconfigure, respectively, differ: while for the Ajuntament it is the international 'rankings' that are of concern, from *Fundación Tierra*'s president's perspective this lacks a more fundamentally 'social' reflection on the nature of existing relations in electricity generation. As such, sustainability icons such as the Pergola 2004 engender a 'sustainable' outcome that is imperfect and lacking in *Fundación Tierra*'s understanding of sustainability, as it remains the case to this day that there are only a few Barcelonans who reap the benefits of (a theme picked up again in Section 6.5).

While perhaps less dramatic than the social upheaval that took place at the Forum of the Cultures, the installation at London's City Hall constitutes another solar heterotopia in the way in which it serves as an arena in which different ideas of sustainability are confronted with one another. For the installation's promoters (the *GLA* and its architects), it was a success on all levels – aesthetically, architecturally, in terms of sustainability: over its lifetime systems are expected to save over 1000 tons of CO2 emissions (LCCA 2005. **#L105**). Lots of lessons were learnt over the course of the project ("And that's the idea of doing them" (Project Manager/engineer, *LCCA*, Interview, London, November 2008)). However, the project is not without its critics. The following extract from an article published in 2008 on the 'London SE community' website illustrates that opponents to the system, while basically agreeing about the need for greater sustainability, were in favour of a 'value for money' kind of sustainability, which the City Hall installation did not conform to, in their eyes:

> Solar panels at City Hall - are they worth the money?
> Thursday 6 March 2008
> […]
> "Reducing carbon emissions in order to tackle climate change is the biggest challenge facing this planet…
>
> But not everyone is so impressed.

> "Solar panels are not cost-effective, especially in northern climes like London," says Damian Hockney, London Assembly member and One London Party mayoral candidate.
>
> "There are plenty of ways to save energy that cost nothing or even save money. Wasting taxpayers' money like this brings the environmental movement into disrepute."
> (Ernst & Young 2011, *Solar panels at City Hall - are they worth the money?*. **#L126**)

While it could be the case that this specific statement is purely political, in terms of Hockney being an opposition candidate, the notion that PV power is an expensive way of meeting carbon reduction targets is pervasive. In Chapter 5 (Section 5.2.2) the subordination of the PV was diagnosed as a chief way in which barriers to its implementation are experienced by the technology's proponents. This form of regime relations often perform a networked-territorial spatiality that is congruent with the nation state owing to the importance of national government technology policy in providing financial architectures that support the technology (see 4.3.4). The tensions that the GLA's leadership utopics performs with respect to established relations in powering are evident in the UK in general. Notorious commentator on energy policy and *The Guardian* columnist George Monbiot, similarly opinions that PV is a "great green rip-off", based on the amount of (government-backed) money it costs for PV to offset carbon emissions:

> The people who sell solar photovoltaic (PV) panels and micro wind turbines in the UK insist they represent a good investment… Assuming – generously – that the rate of installation keeps accelerating, this suggests a saving of about 20m tonnes of CO_2 by 2030. The estimated price by then is £8.6bn. This means it will cost about £430 to save one tonne of CO_2… you could save a tonne of CO_2 for £3 by investing in geothermal energy, or for £8 by building a nuclear power plant.
> (Monbiot 2010, *Are we really going to let ourselves be duped into this solar panel ripoff?, The Guardian*, 2 March 2010. **#L153**)

Whatever the accuracy of these figures (which has been challenged by solar supporters; e.g. UK-PV (2010) – evidently, these debates on the 'carbon merits' of technologies such as PV transcend individual systems. However the high profile character of urban icons such as City Hall and the Forum Pergola means that they may act as sites through which different understandings of sustainability are contested, whether 'carbon' or other. Viewing these as heterotopia enables to tease apart conflicting understandings of sustainability, as in the case of the protestors, the *Ajuntament* and activists such as Pep Puig and *Fundación Tierra*, and solar supporters and opponents, as in the case of the *GLA* and its executive arm (*LCCA*), and critical commentators as Hockney and Monbiot. While contested and 'in between' the sustainability aspired to by their creators, they act as powerful nexuses around which debates, disagreements and protests concerning the directions of sustainable change are fought out.

The following section considers how, in a more expansive manner, the entire urban territory may become a solar heterotopia, as novel perspectives upon the city are opened up by those aspiring to transform cities from mere passive consumers of energy into power plants.

6.4 The resource city

PV, as a non-centralised and renewable electricity converter is deeply implicated in processes of reconfiguring the city through rethinking territorial spatial energy relationship to its wider hinterlands. Such aspirations are frequently expressed in texts (see 4.3.2) such as urban, regional and national public policy documents (e.g. GLA 2007; Mairie de Paris 2006a; Ajuntament de Barcelona 2003b). With respect to such urban strategies specifically this has translated into the ambition to attenuate geographical resource dependencies to remote hinterlands through seeking greater independence from national infrastructures, 'out of town' power stations, such as through energy decentralisation, and the related decarbonisation of energy supply (Hodson and Marvin 2010). In other words, energy – electricity and heat – ought to be produced within the urban boundary. A crucial aspect of this process of energy 'decentralisation' is the creation of alternative ways of imagining the urban as a resource space. The pondering of urban spaces' energetic quality is illustrated by this interview extract with a Parisian interviewee from the Mayor's office:

> At the moment, what is even possible in Paris in terms of renewables? Hydroelectricity, putting turbines in the Seine, yes it's possible in narrow places, but that's where boats also go, so we'd have some problems. Wind turbines, I don't mind [laughs] but, it's difficult, maybe if we come up with vertical [turbine] axes and noiseless machines… yes and then

> biomass faces air quality limitations here in Paris. Maybe a bit of geothermal in the south of Paris. And then, well solar. On rooftops, well anywhere really.
> (Energy Advisor, *PASU*, Interview, Paris, May 2009)

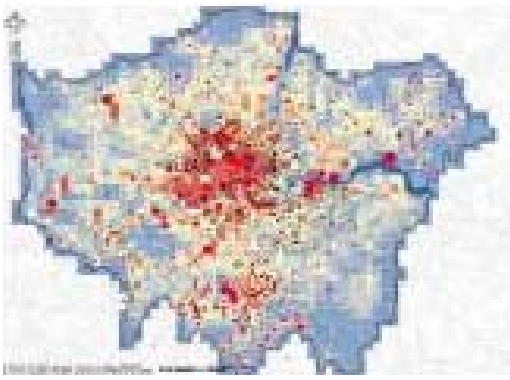
Indeed, representations of the urban as not a passive consumer of resources, but a site that is itself endowed with the potential for localised energy generation, are emerging. For instance, urban 'energy maps', such as those in Figure 6.5, cast a new perspective on the city as space of energy resource. London's 'heat map', for instance, publicly accessibly via the internet, provides data on a range of factors such as CO2 emissions, energy supply, energy demand densities and fuel consumption. According to the London Mayor Johnson's 2010 Draft consultation 'Delivering London's Energy Future' (GLA 2010: 75) it "is an online interactive tool that provides spatial intelligence on DE [decentralised energy], allowing users to identify opportunities for DE projects in London". With respect to PV specifically, the 'London Plan' (2008) states that 45 MW and 36 MW of PV capacity could be installed on domestic and commercial buildings, respectively. The network diagram of Barcelona's energy production and consumption flows (Figure 6.5-2) contained in the city's Energy Improvement Plan (*Pla de Millora Energètica de Barcelona – PMEB*) portrays Barcelona not through using the commonplace Euclidean map of the geographical city (as in for instance in Figure 4.7) but as a network space of energy flows between production and consumption centres. The bottom influxes at the far left of the diagram represent Catalan grid electricity into the city, the far right Barcelona's total energy consumption, while the section in the middle allocates electricity produced and consumed to Barcelona's different sectors and their demands for particular types of energy (e.g. gas, transport fuel, electricity, heating). The document further estimates that the city could accommodate 14.1 MW of PV power on a range of public, private and commercial surfaces.

The mapping of the energy city makes it possible to view and interpret urban space in novel and unusual ways. Energy maps, as alternative representations of urban space, are less concerned with geographical physical and territorial boundaries than with the interconnection of energy flows across space. In the process, several urban spaces become reinterpreted as constituting resources for sustainability. Existing and new buildings, public space and transport infrastructures are some of the urban assemblages (see 5.3.4) that become potential sites of solar electricity generation. With respect to the latter, a study for the Mayor's Energy Strategy (GLA 2004: 174) states that "a number of systems, mounted along a total of 10km of London Transport routes, could contain a total installed capacity of 1.56MW, providing an electricity yield of 1.2GWh/year". The availability of this kind of knowledge enables the GLA to formulate 'Proposal 41' in the Climate Change Action Plan:

> Proposal 41 The Mayor requests Transport for London to install photovoltaics to power street applications, such as street lights, bus shelters and bus stops, where viable…
> TfL should investigate such potentially sizeable and high-profile schemes, which could be integrated with traffic noise barriers where these are practical.

In a city such as London, with electricity demands in the 'terra-' rather than 'giga-' watt magnitudes, 1.2 gigawatt hours may seem negligible; however, thinking urban space as energetically valuable constitutes a fundamental departure form how these spaces have been traditionally thought about, and treated in policy and practice. It suggests that the electric possibilities that are latent in decentralised energy technologies such as PV are crucial in the process of unsettling established conceptions surrounding processes of powering the urban. They make it possible to question and open up to contestation the fixity of boundaries between features such as cities, electricity systems, and their interconnection by means of transmission lines.

Here the innovative utopic of problem-solving (see 5.4.4) becomes an important practice for constituting the territorial city as a heterotopic space of energy resource. In particular the systematic processes of knowledge creation (through reports, modelling and other quantifications), which problem-solving often involves, emerge as important in performing the 'resource city'. Through providing alternative ways of representing urban space they form the basis from which actors may begin to deviate and disorder established relations of centralised energy geographies. In the case of PV specifically, through processes of knowledge creation and its associated representations of the urban the city becomes understood as endowed with resources beyond the purely climatic. Contrary to the irradiation resource maps that one frequently sees summarizing the solar potential of entire countries and continents (e.g. Figure 1.4), urban solar maps include considerations of built structures, available (roof) surfaces, and their inclination (Figure 6.5). And methods for calculating urban solar resource are evolving considerably. They range, for instance, between estimating roof space from the footprint of buildings (derived from polygon measures using ordinance survey layers, as in the London Carbon Scenarios report (SEA/RENUE 2006), to more sophisticated 'urban solar atlases' which are compiled from aerial photography. The latter constitute the state of the art – Figure 6.5 shows how information about solar potential is made available in a geographical information system about an entire capital city (here, Berlin, Germany). With the click of a mouse, homeowners, as well as commercial firms, may establish whether installing PV on any particular urban roof would be a worthwhile undertaking in terms of roof space, system size, investment costs and carbon mitigation.



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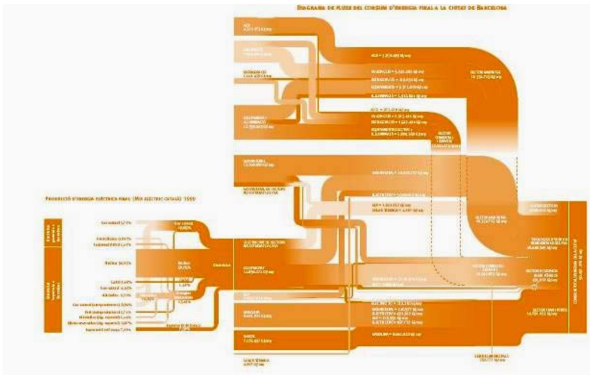

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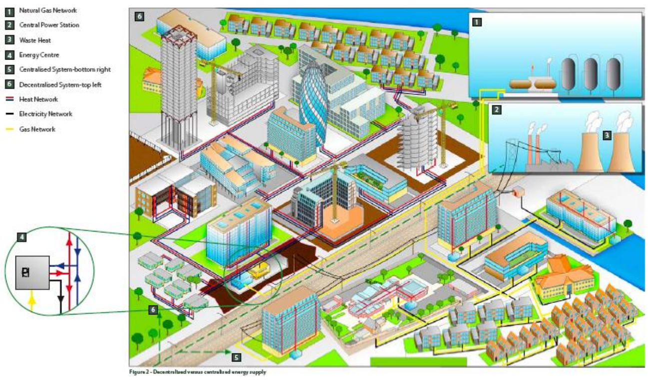

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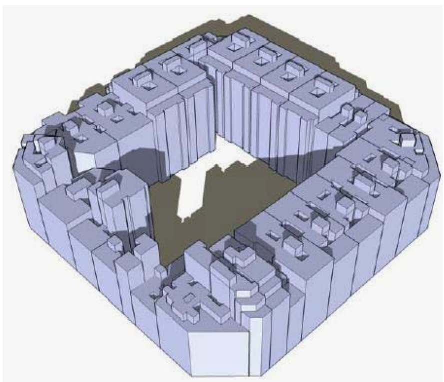

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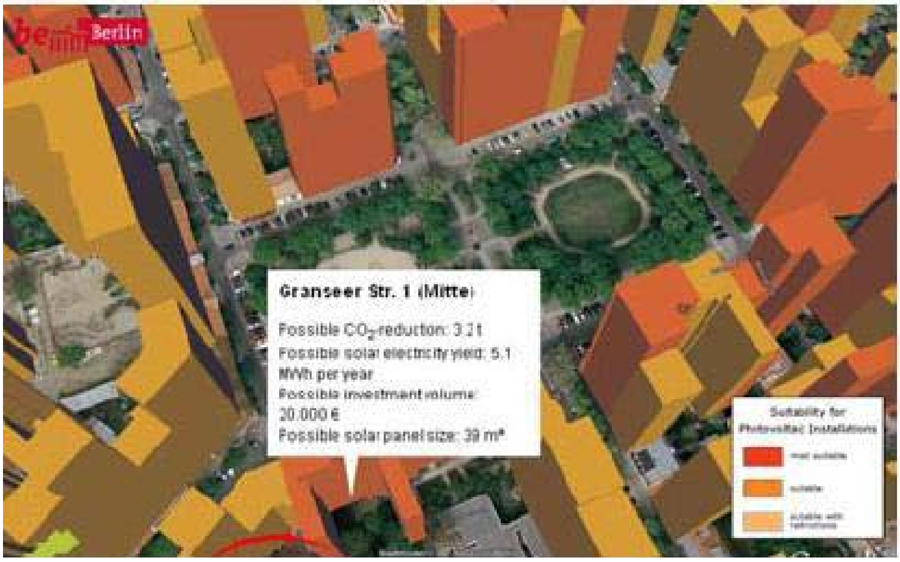
Figure 6.5 Resource cities

(Source: [1]Mayor of London 2010, *Delivering London's energy future*. **#L135**; [2]Ajuntament de Barcelona 2003b, *Pla De Millora Energètica De Barcelona*. **#B26**; [3]London First 2008, *Cutting the Capital's Carbon Footprint*. **#L121**; [4]Bosque Garcia and Domingo Marín 2008, *L'energia solar fotovoltaica com una alternativa en els espais urbans*. **#B48**)



"A new solar atlas finds that the cloudy German capital could cover 77 percent of electricity consumption in homes from solar power on "suitable roofs.""

Figure 6.6 Berlin solar atlas
(Source: virtualcitySYSTEMS 2008. **#G16**)

However, while these new knowledges effectively provide the new conditions of possibility for 'energising' urban space, Hodson and Marvin (2009; 2010) note that processes of decentralising and decarbonising urban energy are highly contested. The authors argue that contemporary urban transformation is characterised by competing claims from different parties 'speaking on behalf of the city', each which may seek to steer and define developments according to their own visions of change, and means for bringing these about. This was certainly the case in London. Opposed to the *Mayor of London*'s push for microgeneration in London, the umbrella business lobby *London First* (London First 2008), has been proactive in generating an 'evidence base' undermining the push for microgeneration through the planning system, as articulated in the London Plan. The understanding of London's low carbon future London First is putting forward is very different than the former Mayor of London, or other actors such as *Solarcentury*, who would like to see a solar panel on 'every building' (see Section 4.4.3). While agreeing on the overall aims of the Mayor's climate protection-focused policy the property developers within London's business community (represented by *London First*) were vocal in their resistance to the Mayor's 'onsite generation' planning policy[67]:

> We support the Mayor's objectives on climate change… BUT – expecting every site to provide decentralised energy and a fifth of it as renewable is inefficient, expensive and technically challenging.
> (London First 2006, *Draft Further Alterations to the London Plan Response from London First.* #L115; capitalization in original)

It is legitimate to say that "the issue of renewable energy was new for the planning system [in particular] the practicalities of using photovoltaics, for example, on tall office buildings" (Rydin 2010: 12); however, the position articulated by *London First* was to questions the very merits of 'onsite' generation, when "there's a whole range of factors you can't take into account for at the design stage, such as management and occupancy" (Project Manager, *Buro Happold*, London, 2008). Rather, London First's response in their report 'Cutting the Capital's Carbon Footprint' (2008) was to argue in favour of other ways of mitigating carbon, in particular, using infrastructure-scale CHP (see Figure 6.6). Whatever the 'carbon merit' of their argument, it is strongly suggestive of how urban space – and in this case 'new' urban space under development – is the site where different ordering strategies come up against one another, through the Mayoral utopics leadership utopics and London First's lobbying (through their evidence-based report). What the latter effected was to divert attention away from a crucial element of the 'onsite generation' policy, namely the emerging embryonic vision of the way new developments are constructed in the future in London – where buildings are no longer mere passive importers of energy, but rather become little power station in themselves.

In contrast, in Barcelona solar activists have used knowledge created about the city to contest what they perceive as the lacking ambition of both the local *Ajuntament de Barcelona* and the regional *Generalitat de Catalunya* in terms of promoting renewables. Bosque Garcia and Domingo Marin's (2008) study into the potential of PV in the *Eixample*, a district of Barcelona characterised by regular architectural form, geographical layout and relatively well-known rooftop usage,

[67] This requires that new developments above a certain size source 20 percent of energy consumption from low carbon energy sources on the development site itself. The 2004 London Plan established a figure of 10 percent, which was increased to 20 percent in the Further Alteration to the London Plan in 2008.

calculated that over 60 percent of domestic electricity consumption in this Barcelonan district could be met by PV if the identified rooftop surfaces were covered with PV panels (Figure 6.4). The authors mobilise these findings in order to argue for a more proactive role to be assumed by the city and regional governments in energy matters, given the solar potential of this district alone:

> It was found that the aims [with respect to PV] of the strategic plans at the autonomous and municipal scale, of Catalonia and Barcelona, respectively, are extremely conservative. As a matter of fact, the Catalan region is not showing a leadership role in the field of renewables and other regions are overtaking Catalonia and becoming references worldwide. We believe that Spain should become a role model in energy matters for other countries to follow, and Catalonia should not overlook this opportunity to become one of the pioneering autonomous communities.
> (Bosque Garcia and Domingo Marin 2008: 78, *L'energia solar fotovoltaica com una alternativa en els espais urbans*. **#B48**)

For activist-intellectual Pep Puig, who was Bosque Garcia and Domingo Marin's academic dissertation supervisor at the time, it was a matter of pushing for a greater 'political ambition' – "because you can enact an ambitious politics, or one that is more conservative. And normally public administrations here do the latter because then at least they can say that they 'got there'" (Intellectual-activist, *Josep 'Pep' Puig*, Interview, Barcelona, March 2009). The Barcelonan example constitutes a rather stark contrast to the case of London's onsite policy, with the ambition of the municipality practically inversed. However in both cases the city becomes enacted as a space of resource potential and as such comes to constitute a nexus through which different visions and attempts to bring these about come up against one another. In contesting and attempting to reconfigure the resource city, the utopics of problem-solving, transgression and leadership utopics here intersect with regime relations that effect to subordinate and exclude PV.

On the whole, therefore, the solar heterotopia of the resource city is not a smooth and unchallenged space in which like-minded actors coordinate around identical visions of what the energy city is or ought to be. Just as knowledge is the basis for formulating targets and interventions, knowledge might equally be mobilised into action through contesting others' ambitions. As a second type of heterotopia, the resource city is a space in which the energy 'identity' of the city is being contested. In the most basic way, through PV the entire geographical city becomes a heterotopia as both its external as well internal boundaries are made permeable through the questioning of energy relationships and realisation of sustainable interventions. This involves mobilising new sets of knowledges which serve as the basis for formulating intention to act. Evidence suggests that interpretations and representations of the resource city are likely to diverge, however the sustainability potential of the very possibilities that are opened up through the creation of such new knowledges and representations should not be underestimated, as suggested by the growing number of municipally- and private sector-led renewable and low carbon (even if not always solar) energy projects across the case study cities.

Implicit to the heterotopia of resource city is that novel relations around energy will be brought into being should electricity actually be generated within the city. The following section turns to explore the heterotopic character of such new decentralised sites of powering, or sites of 'prosumption', in which the acts of producing and consuming electricity begin to blur and become congruent.

6.5 Sites of prosumption

As contested as the heterotopia of the energy city, is the emergence of new material, technological, social, economic relationships around energy consumption and production. As energy becomes a commodity that is no longer just imported into the city, but also generated, new forms of socio-economic relationships of service provision emerge, around PV and other non-centralised technologies. As Walker and Cass (2007) explore, decentralisation is enabling novel combination of technological 'hardwares' and 'softwares'. The authors note how, in the UK context, five 'modes of implementation' of renewable energy are crystallising ('public utility', 'private supplier', 'community', 'household' and 'business'). Whatever the precise merits of Walker and Cass's categories, evidence suggests that through grid-connected PVs and the meter which oversees the in- and outflows of grid-connected systems are more than just symbolic of a relationship that is no longer unidirectional. What new sites of decentralised solar powering have in common is that they constitute spaces in which a fundamental departure from centralised fossil fuel based powering: they disrupt the dominant 'client' relationship between energy consumers and utilities characteristic of the centralised model. Significantly, 'decentralised' powering changes what kind of power is generated, where and by whom. These spaces of decentralised generation are here understood as 'sites of prosumption'[68], to indicate that they constitute a collapsing of the geographical separation of power *pro*duction and con*sumption* that is characteristic of the established, centralised model.

As such, the whole range of urban PVs that have been explored over the course of this thesis – municipal PV installations, solar guerrillas, domestic and community systems, public art and urban icons – are all actual spaces in which the uni-directional flow of electricity, characteristic of centralised powering, is disordered. In Barcelona, Solar Guerrilleros illicitly plug the sun into the national grid using their guerrilla panels. In Paris, the shared ownership 'Copro' initiative (see Section 4.4.4), however precarious, is another case of prosumption in which the consumption and production divide of the centralised paradigm is breached. Shared ownership buildings' owners and inhabitants are being mobilised towards becoming involved with energy efficiency and renewable energy through PV. Sites of prosumption thus make permeable and fluid the boundaries between the city, power stations and transmission lines, consumers, producers, energy utilities and non-traditional generators. A key aspect of the heterotopic character of sites of prosumption is the emergence of new relationships around PV, as solar electricity becomes traded as a monetarily valued commodity through new business models that contain a very different consumer-client relationship than that between the energy provider and the end user.

For existing energy utilities, there is little that is attractive about prosumption. As this London-based interviewee muses, rooftop power generation is not likely to constitute a profitable business endeavour that fits into existing generators' portfolio of power generation:

> Utilities are perhaps another issue… *In theory* [pauses] they could be making money out of it… It's just another form of generation. So you could have companies paying to use your

[68] The term 'prosumption is sometimes used to refer to the combination of *pro*fessional and *con*sumer (as in digital camera product ranges) to denote a professional-consumer market segment. Denoting the collapsing of *pro*ducer and *con*sumer, the notion of prosumption has been around since the 1980s with reference to consumer electronics and more recently the web 2.0. It refers to consumer involvement in value-producing processes, however, to my best knowledge has not been used substantively in the context of electricity microgeneration, besides in a paper that arose from this thesis, Maassen (forthcoming 2012). Walker and Cass (2007) talk of 'co-provisioning', which has slightly different connotations than prosumption as it is used in this thesis. However, they similarly identify a trend of diversification in the socio-economic energy models.

> roof space[69,70]. Whether they think about it and how it fits into their business planning and whether it's against their core interests is the issue.
> (Managing Director, *Carbon Descent*, Interview, London, November 2008)

For incumbent large scale generators it is not clear where the profit of power generation is to be extracted from prosumption, given that lacks the economies of scale of centralised generation. As London-based interview representing large utilities in the UK explains, "if it's financially viable and it makes sense in their business portfolio, then they'll do it" (Head of Policy, *UKBCSE*, Interview, London, November 2008). Decentralised generation, in particular using solar power, however, manifestly does not make 'business sense'. It simply does not fit with either the self-perception of utilities as not only the sole, monopolistic generators of power and, crucially, with their business mission of supplying power in a reliable and secure manner (ibid.). In this context, the intermittency of supply deriving from the diurnal and weather-dependent fluctuations in solar radiation loads means that PV power is often not thought of as a worthwhile enterprise for many existing utilities. Prosumption, in other words, is thus fundamentally disruptive of the existing material, social and economic fabric of powering.

However, despite constituting a substantial socio-economic and spatial deviation from the centralised status quo, sites of prosumption are not – at least necessarily – free from their own problematic 'unsustainabilities'. For instance, attention has been draw to the fact that the benefits of prosumption often remain the privilege of an 'able to pay' elite. Amongst such groups, 'David Elridge', a 'regular' retiring citizen may install solar panels on his semi-detached property "as a hobby" (see Figure 6.6). He can do this because he is financially well-off enough to 'match-fund' the installation after UK government put up the other half of the system's costs. While the industry evolves, sometimes even rapidly (and 'progressively' as Section 5.4.1 explored), at the time of fieldwork, and for the coming years, PV remains a relatively expensive technology, associated with substantial upfront costs. As such it is not possible for everyone to be "economic,

[69] At the time of research in November 2008 'rent-a-roof' (RAR) schemes did not exist in the UK as there was no feed-in tariff in place. An RAR business model revolves around a third party renting the roof space of a property owner and reaping the feed-in tariff for the sale of electricity generated. Mendonça (2011) estimates that RAR schemes constituted approximately 20 percent of the UK market in early 2011.
[70] While in Barcelona-Spain and Paris-France such schemes are relatively uncommon (at least in cities), in the UK, rent-a-roof schemes were estimated to constitute 20% of the UK PV market in early 2011 (Mendonza 2011).

efficient and green", as perhaps those aspiring for eco-empowerment (and indeed, livelihoods) would like it. Like Elridge's domestic system, in Barcelona *Fundación Tierra*'s 'Solar Wave' participatory project subverts grid power through re-locating electricity generation into the city (on a municipal market roof). Ownership of the system resides with multiple parties, who each put up around 1,000 Euros of upfront investment. While this constitutes a fundamental departure from grid electricity, both in terms of socio-economic organisation as well as the metaphorical investors' relationship with energy (see Figure 6.7), the possibility for becoming the 'stockholder' of a PV installation is, again, associated with a capital investment that is available to 'Yolanda Delgado' but not the majority of Barcelonans.

The initial idea

When he retired in 2002, David Eldridge thought he would construct a low voltage photovoltaic system as a hobby, for driving low energy appliances. Shortly afterwards, his local Energy Efficiency Advice Centre (EEAC) invited him to complete a Home Energy Check questionnaire to assess the energy efficiency of his home. In the report he received back from the EEAC, there was also some information about installing a solar hot water system. David began researching the possibilities for his own home.

Figure 6.7 'David Elridge'
(Source: DTI/EST 2005, PV Grant Programme – David Eldridge. **#L37**)

However, a range of new forms of public-private and commercial enterprises that are emerging around decentralised powering promise to broaden access to a wider spectrum of the urban population. These further feed into the solar heterotopia of prosumption. In Paris, for instance, a public sector-led energy services company (ESCo), SOLARVIP, will begin operations in 2012. The company will manage around 40,000 square meters of PV panels on approximately 30 different buildings belonging to a large municipal development (the Eco-ZAC Clichy-Batignolles) in Paris' 17th *arrondissement*. The set up is such that the ESCo will initially rent the roofs of buildings from the party financing the panels (in this case the municipality) and, once panels are repaid (through the national feed-in tariff), the lease is transferred to the building owners, who then receive roof rental income; while SOLARVIP continues to collect the proceeds from electricity sold to the utility under the feed-in tariff. As the risks are borne by the 'project promoter' (in this case the municipality) such ESCo ‘rent-a-roof’ schemes are deemed a possible avenue through which those not ‘able to pay’ the upfront investment may benefit from solar power. However, some have warned that being the owner of a system is financially more advantageous by a factor of up to 15 (The Guardian 2010. **#L195**and **#L196**; Consumer Focus 2010. **#L19**).

> “This [participatory] system involves regular people in renewable energy, a privilege previously of only corporate entities. As a result, 145 people have learned what solar energy is. And they now look at the sky very differently.
>
> …Yolanda is convinced that citizens can contribute to mitigating climate change as long as they feel "part of the solution."”

Figure 6.8 ‘Solar stockholder’ Yolanda Delgado
(Source: La Vanguardia 2007, *Hay que apoyar más la energía solar*. **#B113**)

Perhaps unsurprisingly, the emerging heterotopia of prosumption does not itself translate into perfect sustainability spaces. RAR schemes, for instance, somewhat dilute the aspiration of some for empowerment, while those seeking to reduce territorial carbon emissions may find that the sort of microgeneration involved in prosumption is but a drop in the ocean. While aspirations for carbon reduction, livelihoods and eco-empowerment have the potentially to coalesce, sites of prosumption take on several forms – inclusive of but not exhausted by RARs, participatory projects, ESCos and full ownership – which are characterised by a diversity of claims upon the new urban spaces of power generation. While it enables some to "look at the sky differently" (La Vanguardia 2007. **#B113**) its benefits, however, are not unconditional or universal.

Having set out three heterotopia around relationships of sustainability and electricity generation, the following section examines in more detail how, as PV arrives in the city, it impacts beyond the realm of power generation. In particular, the existence of solar schools may formatively shape young people today into energy citizens of tomorrow.

6.6 Solar schools

1

2

And before the question is asked I will answer it. It's not a huge system, however, everyone is agreed that it is largely putting it in the faces of children, making it real for them, the educational component.
(Project manager, *Solarcentury*, Interview, London, November 2008)

Figure 6.9 Solar schools
(Source: [1]PV upscale 2004, *Strategies for the development of PV in Barcelona*. **#B125**; [2]Agència d'Energia de Barcelona/Ajuntament de Barcelona, Fitxes de les 8 escoles: Instal·lacions fotovoltaiques en escoles de Barcelona. **#B10**)

Solar schools are perhaps the least contested solar heterotopia identified by the analysis. In contrast to contentious sustainability icons, the hotly contested resource city and the ambivalent promise of sites of prosumption, solar schools are relatively uncontroversial. While there is little disagreement about educating next generation about energy consumption, the substantive significance of solar schools derives from constituting a site of transformation. In this concluding analysis section of the chapter and thesis, solar schools are presented as tangible spaces in which everyday encounters with energy are opened up for negotiation and reconfigured and may effect generational changes in engagements with energy. Solar schools are only found in Barcelona and London, while in Paris, as a late starter in things solar, PV has featured as an educational device mostly as different organisations and private individuals participate in the 'European Solar Days'[71]. While PV has yet to become mainstreamed into schools, in Barcelona and London PV has been promoted more explicitly in the educational system through municipal PV demonstration programmes (Barcelona) and corporate social responsibility projects (London). In Barcelona the school projects have tended to take a more technical orientation (in terms of experimenting with different forms of building integration rather than focusing more explicitly on PV's educational component).

In London, in contrast, *Solarcentury's* solar4schools initiative, as already touched upon in Chapter 4 (Sections 4.2.3 and 4.4.3), explicitly articulates aspirations about PV's "huge potential for educating next generations" (*Solarcentury* 2009, **#L187**). As *Solarcentury*'s solar4schools project manager states,

> So it's a four kW system that is meant to say to children 'the grownups are doing something about all these things that you're hearing about all the time and by the way, here's how it works and here's an opportunity to learn about, and make it part of your everyday life'. Same as computers are part of their everyday life in a way that they weren't part of my growing up everyday life. That's the ethos behind it.
> (Project manager, *Solarcentury*, Interview, London, November 2008)

[71] Over the course of several days each year, public awareness raising events take place and specific solar installations are opened up to the public for demonstration.

It is not simply the case that pupils are exposed to solar panels on a daily basis as passive onlookers. Solar4schools provides educational materials – "a little box of solar panels, motors, wires, clips instructions and educational materials, a CD of lesson plans" (ibid.) – for teaching children about how PV specifically works, and how it relates to concerns over climate change. The heterotopic quality of solar schools derives from the way they provide spaces in which the younger generation is inculcated with the imperatives of reframing and reconfiguring the individual's relationship to energy consumption in the context of a changing climate. For instance, the promotional video shows several scenes in which this is taking place (see Figure 6.10). Besides interactive contact with miniature solar panels, pupils are taught through the lesson plans provided that there is link between "global warming" and "carbon burning". A group of children is placed before the camera, encouraging others to "cut your carbon footprint". Whether it is the case of *Solarcentury* raising "its next generation of clients" (an interviewee, wishing to remain anonymous on this statement), it does appear as though the solar school emerges a site in which future generations are educated along energy conscious principles.

Importantly, the effects of PV installations on schools transcend the boundaries of the actual system and the school. They are (at least thought to) spill over into a myriad of places and people that are woven into the daily lives of children; from the school to the household, extra-curricular activities and leisure, including teachers, members of the family (parents, grandparents, siblings). A Head Teacher featured in *Solarcentury*'s video describes the impacts of PV in schools as a matter of generational change:

> the children will go home and talk to their parents and grand parents and I think in that way the younger people will educate the older generation, which is obviously necessary… [Helen Cryer, Headteacher Peacehaven community school in *Solarcentury* 2009, *Solar for Schools Promotional video*. **#L187**)

This sentiment of solar schools being part of a broader trend of transgenerational exchange and transformation is echoed by several key figures featured in the solar4schools projects promotional literature. While it remains open to question (and future research) whether solar schools are having the intended effects, the promotional video certainly conveys this message. For instance, late in the video, a young boy is filmed saying, "I like the generators because they don't cause pollution and they're good for the environment" (4.20min). As 'energy sustainability' becomes a routine notion in children daily practices, a relevant question emerges concerning the sustainability impacts of these future energy citizens. An energy advisor in a London-based energy agency suggests, that energy and sustainability is becoming a realm of activity and employment that will have a similar appeal to future graduates as corporate advertising and investment banking has had previously.

> younger people are and will be coming in because they think it's a cool and interesting area to come in… it's got that 'ooh' factor. Young people used to say 'I'm going to go into advertising, wow that's really cool' and now I think if you're going to do something that is a bit more socially responsible, then that's the cool thing to do.
> (Energy Advisor, *CEN*, Interview, London, November 2008)

As such, children educated in energy sustainability today, may translate into tomorrow's 'sustainable' citizens and workforce.

"It's all about global warming. What's the link? Burning stuff, global warming. What's the bit in the middle, what's creating the global warming?
"carbon dox…"
"carbon dioxide, yes!".
[1.52-1.55 min]

"I like the generators because they don't cause pollution and they're good for the environment" [4.20min]

"cut your carbon footprint" [4.50min]

Figure 6.10 Future energy citizens
(Source: *Solarcentury* 2009, *Solar for Schools Promotional video*. **#L187**)

6.7 Conclusion

This chapter sought to develop an understanding of unfolding change through an engagement with the relational 'work' that technologies such as PV perform in terms of reconfiguring existing, 'unsustainable' relations. The chapter explored how technologies themselves are implicated in making intelligible that which is undergoing change. By constituting a material-discursive 'other' to existing alternatives, PV (among other technologies) acts as a nexus around which a range of 'unsustainabilities' are un-black-boxed. Crucially, unlike for instance power cuts, once enacted these do not become obscured when the lights go back on. At the intersection of actors innovative utopics and the regimes that are in place the conditions for more 'sustainable' futures are emerging. Solar heterotopia were cast as the spatial and material relational gateways that emerge at the intersection of a diversity of ordering strategies, which are the utopical sustainability interventions and those forces that reproduce of existing relations. While each promises a qualitative departure from the 'unsustainabilities' of the status quo, none is an unproblematically 'superior' spaces of perfect 'sustainability'. Neither are they merely 'stepping stones' or 'missing links' to a future forms of sustainable. Instead the heterotopia of the solar city are in-between spaces whose drifting contingency suspends them in a constant and open-ended state of negotiation.

In the *Badlands of Modernity*, Hetherington proposes that the importance of 'the factory', as a heterotopic space associated with the emergence of modernity, were its effects of changing conceptions of 'the individual' and their contractual freedoms, through fundamentally reordering the spatial and temporal organisation of the workplace. Hetherington (1997: 138) states that

> the effectiveness of the ordering of the factory, while not certain or uniform, and certainly not free from resistance to its logic, allowed it: first, to influence the way in which production was carried out within the domestic systems; second, to produce distinct spaces with which the domestic system could not compete; and third, to come to dominate the mode of production within industrial capitalism.

In contrast to this account, solar heterotopias are unlikely to dominate urban electricity, at least in the near future. However, as 'sustainability' heterotopias more broadly, solar heterotopia create spaces that are 'in-between' the normal and novel. As a result, PV is having the effect of significantly dis- and re-ordering material and discursive relationships around energy, involving, consumers, producers, new sites and subjects of powering, new technologies and energy citizens. Following Hetherington, it can be argued that these work to reconfigure internal boundaries of social space in ways that provide a departure from the 'unsustainabilities' performed with respect to the 'status quo'. Most basically, the role of a technology such as PV can be seen as providing the basis upon which alternatives are engendered and spatialised. It was argued that the heterotopic effects of PV – tied up with meanings of sustainable change, the nature of what constitutes resources, the way in which these ought to be exploited, and modern urban subjectivity – are such that they are not contained within the physical space of technological installation, but spill over far beyond the confines of its territorial spatiality. As such, heterotopia are sites of otherness, in and through which alternate ordering strategies are being engaged (Hetherington 1997), and which engender spaces of ambiguity and contestations as different aspirations for change and diversity of sustainability politics diffract.

7 Conclusion

7.1 Introduction

The thesis' concern is whether and how photovoltaic (PV) technology has come not only 'from space to earth' (Perlin 2000) but also to the city; in particular in the context of technology-related urban transformation for sustainability. This question is made concrete around a focus of inquiry on innovation in urban photovoltaics in three European cities: Barcelona (Spain), London (UK) and Paris (France); which constitute empirical contrasts in the European PV context. The study is a qualitative analysis of a wide range of documentary sources and three in situ fieldwork periods during which interviews were conducted and several events attended. Documentary evidence was obtained predominantly from the internet and included policy documents, technical and advocacy reports, consultancy responses, and promotional material. Interviews were conducted with policy, advocacy, and industry actors and practitioners involved in the delivery of PV. Events included publicly and privately organised occasions. These evidence sources form the empirical basis of the thesis which was analysed and interpreted through a conceptual framework that was specifically developed for answering the thesis' research questions:

1. What is the evidence of the emergence of PV in European cities?
2. Is there evidence of variation across different urban and national contexts?
3. What factors have facilitated the development of urban PV?
4. What factors have impeded the development of urban PV?
5. What are the prospects for urban PV?

The thesis began with an exploration of innovation studies literatures which have engaged with the topic of PV. This was a natural starting point given innovation studies' explicit focus on how technology, ideas and processes becomes normalised ('diffused', 'taken up', 'embedded') into mainstream society. Engagements with these literatures, in particular Strategic Niche Management and the Multi-level Perspective (*SNM*/*MLP*), led to the formulation of three main lines of inquiry based on how the problem of innovation is understood. In the first instance, innovation is framed as an interplay between that which is novel (i.e. 'technology') and that which is 'normal' (i.e. 'contexts' that predate novelty). Secondly, attention has focused on the role of technologies, such as PV and other 'green' energy generators, in broader sustainable transformations, in particular in the environmental innovation branch of innovation studies, concerned 'with sustainability transitions'. Third, in particular policy-orientated strands of innovation studies such as *SNM*/*MLP*, have drawn attention to the prospects for purposeful interventions to foster new technologies. Thus broadly framed through a lens of innovation, the thesis however fundamentally departs from existing approaches in innovation studies in terms of thematic orientation and conceptual disposition.

Chapter 2 explored at length how understanding innovation in urban PV requires an approach that is attuned to the relationship between technology and the city, the politics of urban technology and the geography of transformation. Concretely, this three-fold critique calls for a more sophisticated understanding of how the nature of technology, the shape and content of purposeful intervention and the relations that are in place relate to the transformative potential of technologies such as PV. The thesis argues that material semiotics provides the conceptual basis from which innovation studies' concerns with novelty, transformation and intervention can be made concrete around urban technology scholarship's themes of materiality, politics and space (see Table 2-1 in Chapter 2). As such, the thesis' conceptual framework was developed from engaging innovation studies and perspectives on urban technology with material semiotics. The latter is less a coherent 'theory of' rather than a theoretical 'commitment to' a range of analytical sensibilities. It developed from actor-network theory and has since expanded (in terms of numbers) and diverged (in terms of empirical themes). However, whatever the focus of inquiry, the common ground is a disposition to treating the world as made up of materially heterogeneous entities which acquire intelligible properties in relation with one another. As such, neither technology nor cities nor actors are understood as self-contained and discrete entities. Rather, they are emergent from heterogeneous relations that entangle a complex array of associational forms; and as such take on a multiplicity of attributes, shapes and sizes. Summarised by the material semiotic notions of material heterogeneity, non-essentialism, relationality, multiplicity and performativity, this abstract ontology was translated into an original framework for theorising innovation in urban PV.

In accordance with the material semiotic foundations of the conceptual framework, comparison is used as an analytical strategy that overarches the specific qualitative methods used over the course of the research. The notion of comparison is used in two related ways. On the one hand, following MacFarlane (2010) 'comparison' is taken to refer to an implicit 'mode of thought' in the way knowledge is constructed – in other words, and in accordance with the thesis' ethico-onto-epistemological position (see Chapter 3), the creation of knowledge is a situated act that is necessarily permeated by an ever-present (and evolving) cognitive and material reference point as the research begins and unfolds. On the other hand, comparison is further mobilised as an overarching research strategy in accordance with an emerging body of 'relational comparative urbanism'. This strand of thought proposes to not take for fixed from the outset the very boundaries of that which is to be compared. The consequence of this shifting, 'relational', understanding of comparison is to avoid analysing cities as foundationally distinct and separate entities in favour of attending to dis-/connected trajectories through which it is not necessarily 'the city' itself that emerges as the most salient unit for comparison. As a result, comparison may take place on several levels simultaneously. The ensuing multiplication of the object being compared has in this thesis generated insights into the diversity of factors shaping innovation in urban PV; for instance: the characteristics and aspirations of actors themselves, their means, techniques and modes of innovating (Chapter 4); the importance of pre-existing configurations in terms of their heterogeneous effects, spatial forms and temporal durations (Chapter 5); and trends in sustainable urban transformation that emerge at the intersection of the former and the latter (Chapter 6).

The thesis' framework takes shape around four key themes in innovation studies: technology, innovation, regimes and transformation. These are used to centre the development of material semiotics as a framework for innovation which accommodates urban technology critiques with the lines of inquiry raised by innovation studies. Capturing its politically ambivalent nature, technology is theorised as made up of a range of building blocks, termed *utopical techniques*, which make up differently working technologies. The utopical attribute is used to indicate that these are entities that are employed to bring about desirable states of affairs, however leaving it open to the process of analysis to reveal how precisely 'desirable' is defined in practice. The act of spatialising aspirations is termed *utopics*, conceptualised as a range of practices through which particular utopical techniques are applied in order to link visions to outcomes. This provides scope to consider, as urban perspectives suggest, multiple sites of and means for intervention. While techniques thus derive their utopical status through actors' attempts to spatialise alternate realities, whether these materials will successfully bring about actors' intended outcomes is related to their interactions with the relations that are already in place – *regimes*. The framework proposes that regimes' precise form and the nature of the constraint they constitute becomes intelligible, co-emergently, through actors' utopics. This provides scope for geographical specificity and contingency as called for by urban technology perspectives. To theorise the outcomes of innovation, the notion of *heterotopia* is introduced. This refers to the spaces that emerge as the utopical techniques that are put to work in actors' utopics interplay and come up against a range of regime relations. The term indicates that the outcomes of innovation are far from actors' aspired-to 'perfect' utopia. While they are 'novel', they oscillate somewhere between the desirable 'utopical' and the 'normal'.

This portrayal of innovation has taken shape in the context of recent developments in innovation studies. While innovation studies is a long-standing field of inquiry with a lineage of growing analytical sophistication (Smith et al. 2010), it has only recently begun to incorporate in a more systematic manner the implications of a geographically sensitive analysis. This has occurred in the context of an intensifying exchange with scholars beyond the immediate field – from anthropology, human geography, sociology, amongst others – who are converging, at least temporarily, in a shared interest in the role innovation for bringing about greater sustainability in existing systems of provision (Rotmans et al. 2001; Raven 2007; Smith et al. 2010; Bulkeley et al. 2010; Coenen et al. 2009; Hodson and Marvin 2010; Shove and Walker 2010; Späth and Rohracher 2010). This thesis contributes to this emerging geographically sensitive thrust in academic scholarship which seeks to understand the potential for, and dynamic of, processes that transform particular places according to new – ecological, social, political – imperatives (however 'sustainability', or indeed other aspirations, are defined in practice). It also speaks to a range of policy actors and practitioners who are grappling with the challenges involved in delivering new technologies into existing environments and practices. The implications of this thesis' findings for scholarship, policy and practice are outlined in Section 7.3. This is followed by a reflection on the thesis' limitations and some future avenues of research that the thesis opens up, which serve as concluding remarks. At present this concluding chapter revisits the thesis' research questions. The research's key findings are discussed under five headings which reflect not the order of the question but rather the way the thesis progressed in answering these.

7.2 Key findings

7.2.1 'Urban' photovoltaics and 'solar cities'

Research question 1: what is the evidence of the emergence of PV in European cities?

The research has generated ample evidence that urban photovoltaics is emerging in European cities; or at least in Barcelona, London and Paris. Numerous PV installations in Barcelona, London and Paris were explored over the course of the preceding chapters, such as the municipal PV projects of the *GLA*, the *Ajuntament de Barcelona* and the *Mairie de Paris*, the participatory 'Solar wave' and the guerrilla panel of *Fundación Tierra*, and *Solarcentury*'s solar schools. These systems all fit a general description as relatively small urban scale electricity generators in terms of the space they take up and their power capacities. They were found to range from the sort of sub-kilowatt magnitudes typical of parking metres and traffic signs to medium systems of at most several hundreds of kilowatts, such as on new and regenerated developments, with a range of in-between sizes on domestic, shared ownership, community and public buildings, and 'iconic' urban architectures. In terms of application types they are standalone (non-building-integrated), panels that are superimposed on existing structures (buildings or other) and different types of building-integrated PVs, such as facades, tiling and shading structures. However, while there is perhaps little that is surprisingly 'urban' about these, the thesis proposed early on that urban PV is a phenomenon that is more intricate than a purely geographical and technical definition would imply.

Figures 7.1-7.3 summarise the constitution of an 'urban PV'. It identifies general features of urban PV, which in this thesis, through its research questions and methodology, are taken to signify the emergence of a specifically 'urban' technology. While little encountered explicitly over the course of research, the notion of 'urban PV' takes shape at the intersection of a number of actors realising their various aspirations about the future. The material semiotic analysis argued that urban PV is a technology that comes to embody the future-orientated, 'utopical' aspirations of a range of actors.

These are invariably related to, however fundamentally transcend, diverse systems' capacity for city-scale electricity generation. Individual or series of artefacts, such as those mentioned above, are entangled in a range of material and discursive relations which generate rather different realities of what constitutes a 'working' technology. As such, depending upon their sociomaterial constitution, the diversity of systems that feature in the thesis are technologies for 'eco-empowerment', 'carbon reduction' and 'livelihoods'; each of which implicates rather different aspirational intentionality. For instance, those using PV for eco-empowerment entangle the technology into their (often activist) practices that seek to align energy consumers according to particular ecological and social ideals through interfering with their entrenched status as customer-clients of large corporations. In contrast, those aspiring for carbon reduction (often municipal and national governments) take a rather more narrow managerial focus as they enrol PV into meeting emission reduction targets and the purposeful upgrading of an often highly sunk building stock. A third set of (often commercial) actors seek to secure their livelihoods and financial gain through expanding their business relationships and customer bases.

Whatever actors' particular reasons for attempting to plug evermore people into the sun, the thesis found that there is more to a 'urban' photovoltaics than (literally) meets the eye. Figures 7.1-7.3 provide a material semiotic visualisation of urban PV in Barcelona, London and Paris. They list the diversity of actors who could be traced by their various techniques, in each city. Actors' aspirations are represented using different colours for their names and the kind of technique is suggested by differently shaped icons. Circles around sets of techniques are used to portray techniques coalescing into utopics – spatial practices – of leadership, critique, synergy and problem-solving. This material semiotic analysis generated a relational account of 'urban PV' technology as both *a vehicle for*, as well as *an emergent effect of*, innovation: emergent from the research process which generated evidence of the technology as a vehicle for realising actors' various aspirations. Through attending to the diversity of aspirations about the future that PV entangles the analysis avoided conflating 'technology' as synonymous with the visible and tangible 'artefact'. While important, specific artefacts are understood as 'fronting' a range of other entities, which must be accounted for. For instance, in Figures 7.1-7.3 each actor is portrayed as generating a range of materials in the process of innovating. Artefacts, but also texts, events and finance were all taken as elemental features of PV's relational constitution as a technology for eco-empowerment, carbon reduction and livelihoods. Through such an inquiry into the various relations that make up a working technology in each case it was found that technologies for eco-empowerment, carbon reduction or livelihood are characterised by a common, sociomaterially heterogeneous 'architecture'. Providing the means through which actors seek to bring about their aspired-to outcomes, this architecture constitutes the building blocks of the relations that make PV purposeful in the context of very different actors' schemes.

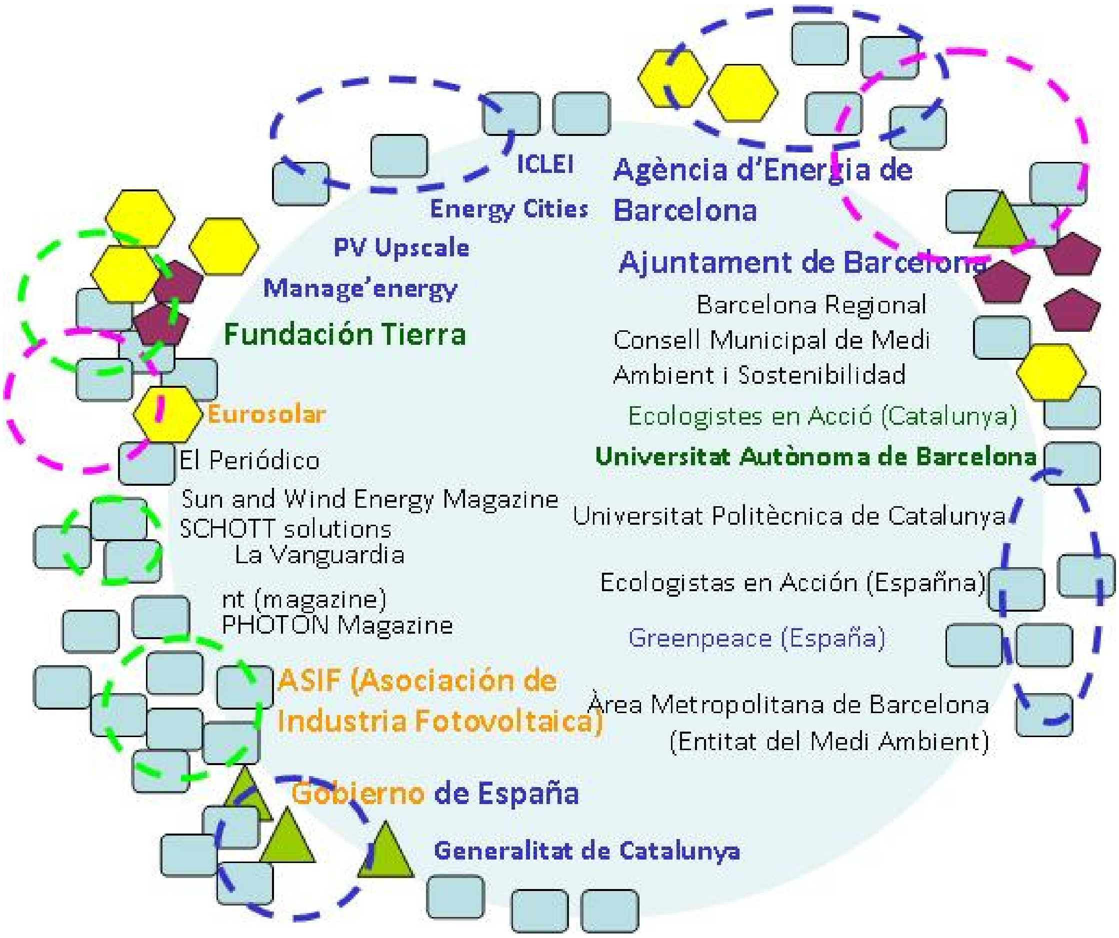


Figure 7.1 Urban PV in Barcelona

It is in the combination of architectural elements that the intelligibility of an 'urban PV' emerges in the context of this thesis. It is specifically 'urban' in the sense that its architecture enacts elements of an emergent – however fragmented and partially coherent – 'solar city'. Analysed in Chapter 6, and further explored in Section 7.2.4, this is made up from a range of in-between sites which come into being at the confluence of actors' utopical aspirations for eco-empowerment, carbon reduction and livelihoods and whatever predates their efforts to spatialise these. As sites in which diverse (re)ordering strategies are engaged they constitute early evidence of the fragmented and partial emergence of 'solar cities' in Europe.

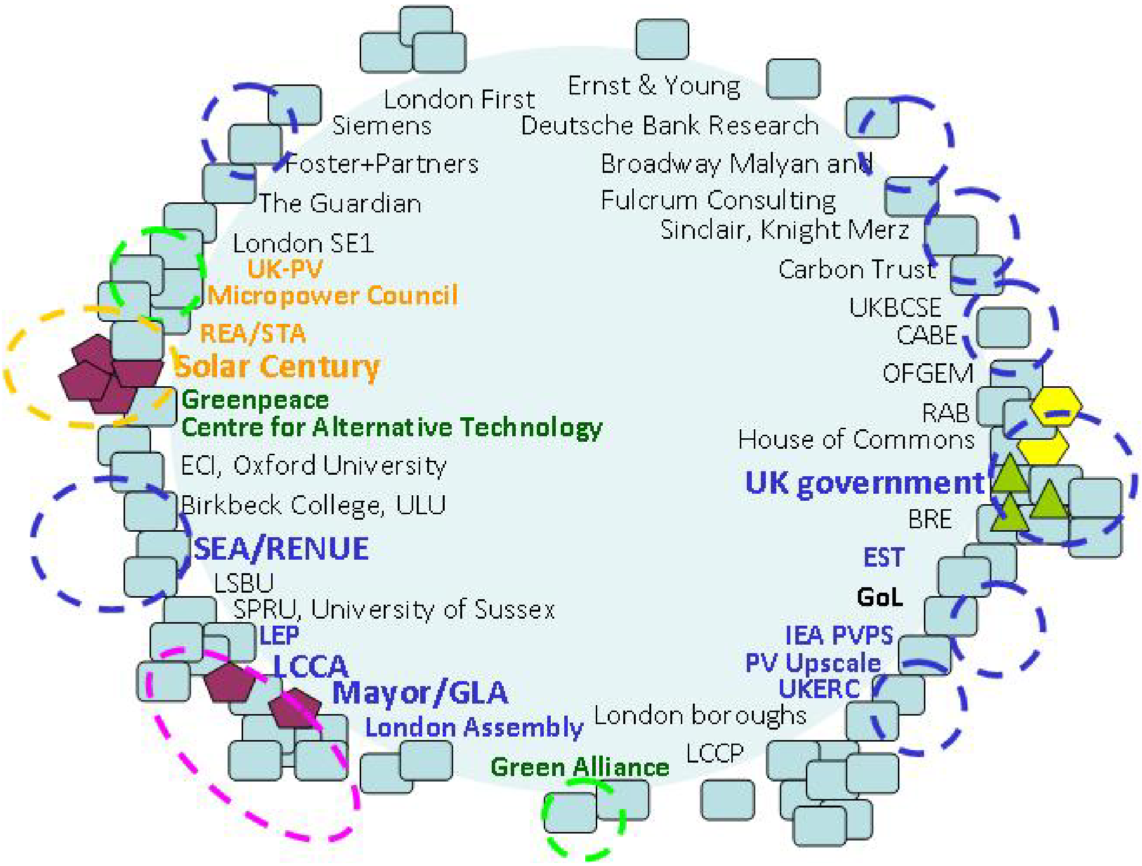


Figure 7.2 Urban PV in London

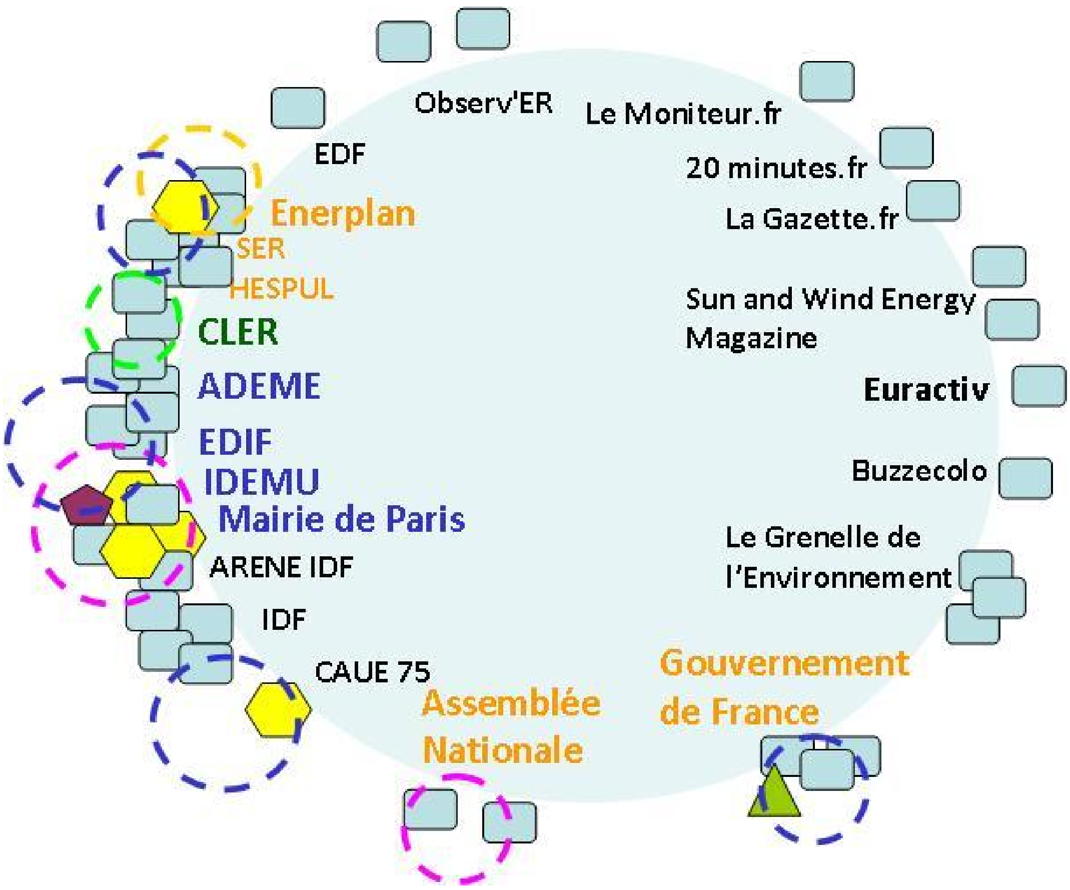


Figure 7.3 Urban PV in Paris

7.2.2 Innovative practice as the driver of innovation

Research question 3: what factors have facilitated the development of urban PV?

The thesis found that outside of actors' efforts to innovate very little is likely to happen in favour of PV. Importantly, however, in building on existing understandings of innovation, as 'innovative' because it involves the introduction of novelty into pre-existing settings, the thesis developed its own original account what is meant by innovation and innovative practice. Specifically, searching for the factors that facilitate the development of urban PV involves focusing on the practices of innovating – utopics – which, the research revealed, take a variety of forms. Utopics is a term that has been central to the thesis as a whole as it is a powerful concept for capturing the means by which actors seek to convert their aspirations into actual states of affairs. It signals a commitment to understanding innovation as involving efforts to spatialise aspirations about somehow desirable futures as alternative relative to that which prevails. However, rather than focusing on a single activity and site of intervention – of 'experimentation' in 'niches', as in the prevailing *SNM*/*MLP* framework – Chapter 4 explored four main utopics through which actors innovate. These involve exemplary practices of 'leadership', imagining transgressive alternatives through a 'critique' of the status quo, galvanising relations of 'synergy' that are mutually beneficial for different actors and a form of 'problem-solving' that is concerned with generating the theoretical technical and practical knowledge and capacity through which others are enabled.

Referring further to Figures 7.1-7.3, a material semiotic analysis, as presented in Section 4.5, makes it possible to parsimoniously portray innovation in urban PV using a geographical lens: the situation in Barcelona, for instance, is dominated by aspirations for carbon reductions (*Ajuntament de Barcelona*, *AEB*, the *Generalitat de Catalunya* at the regional level, the Spanish state and a range of European scale cooperative arrangements), and livelihoods (the Spanish state in earlier years, and notably the industry lobby group *ASIF*). These various actors innovate through leadership and problem-solving, and non-governmental actors (e.g. *Fundación Tierra*) in particular through critique. As Chapter 4 explored, in the Barcelonan case leadership-problem-solving of the *Ajuntament* and the *AEB* was no treadily compatible with *Fundación Tierra*'s rather more radical demands for eco-empowerment. In London, in contrast, limited aspirations for eco-empowerment are countered by strong commitments by a range of actors to carbon reductions (a range of European associations as well as the Mayor, the *LCCA*, the UK Government and a number of national advisory bodies). This is paralleled by the presence of livelihood aspirations by a commercial actors such as *Solarcentury* and the *Solar trade Association* (*STA*). Through the synergy between the two, the Mayoral leadership and various problem-solving utopics have worked in concert in London, generating a range of urban demonstration projects and social, political and commercial alliances between public, private and non-profit sectors. This is strongly contrasted by the Parisian context, in which little evidence of PV artefacts was in fact found – neither of the PV systems on the ZAC Pajol, Carreaux du Temple or Eco-ZAC Clichy-Batignolles had yet been installed. Actual PV artefacts in Paris are rather overshadowed by the launch of a national industry of excellence, and their rhetorical value as emblems for changing urban development priorities. Here a range of actors were revealed as innovating out of aspirations for livelihoods (such as the French Government, *Enerplan* and *HESPUL*), while others, the *Mairie de Paris* and non-profit actors pushed for carbon reductions through a diversity of leadership and problem-solving strategies.

On the whole, while thus lending itself to a geographical account, through the notion of utopics the material semiotic analysis provides a layered account of general features of innovation: as taking a variety of forms (utopics) owing to the diversity of means (techniques) available to different actors in practice. Rather than localised in orchestrated niches and exclusively concerned with 'learning', utopics are constituted through the relationship between the diverse elements of urban PVs sociomaterial architecture – artefacts, texts, events and finance. As portrayed in Figures 7.1-7.3, these may, put together, constitute utopics. For instance, leadership involves a range of exemplary artefacts, verbal and written rhetorical statements of intention and promotional materials. In contrast, critique works through pushing the limits of the legal and accepted through a range of textual means (e.g. 'manifestos', mocking 'grey papers') and transgessive artefacts that set legal and technical precedents through involving the legislator and the media; turning regular citizens into 'solar stockholders' through participatory PV installations, as well as through more 'playful' interventions such as solar cooking events which subvert conventional understandings of energy consumption and generation. A third utopic was that of synergy which works through a range of artefact products, business relationships forged across different professional groups and the harnessing of – financial, political – energies of actors otherwise not involved with PV; for instance through corporate social responsibility initiatives. In contrast, the problem-solving utopic of a range of actors – such as consultants and local energy agencies, but there are others – generate a range of technical reports, information and guidance leaflets which gather in the space of the text or the project different actors, spaces and materials to provide analysis and advice; often informing other utopics.

There is thus a common architecture to different utopics – and these are themselves constitutive of the specific dynamics of innovation. In particular, the extent to which different actors enact any particular utopic is related to what is already in place. On the one hand, while for instance the governments of France, Spain and the UK are able to leverage significant funds (e.g. through grant funding and feed-in tariffs), the same financial capacity is not available to municipal, private sector actors or advocacy groups. These may work through appealing to more institutionally powerful actors or to corporate actors and civil society using transgressive texts and artefacts, but also through projects and events that play on the political kudos that can be derived from PV's 'green' credentials. On the other hand, the impetus behind the directions of actors' utopics are formatively shaped by their aspirations for interfering with *specific* relations; whether these are what they might perceive as the 'unsustainabilities' of the status quo or, more opportunistically, to create a business opportunity where there previously was none. Whatever the precise aspirations and the particular ways of spatialising these, utopics is what drives innovation, as it involves the deployment of the means through which aspirations for novelty could be made a material reality. However, as *attempts* to spatialise novelty, it is not only the shape and direction of utopics that are formatively shaped by that which is in place – the extent to which utopics are successful in bringing about the aspired-to states of affairs is also often significantly reduced by the prevailing conditions of possibility.

7.2.3 The problematic implementation of urban PV

Research question 4: what factors have impeded the development of urban PV?

The research found that innovation in urban PV is 'problematic' owing to the fact that efforts to innovate are constrained by the conditions of possibility constituted by regimes. That regimes pose challenges to innovation is not new to innovation studies, however in the context of this thesis the term has taken on a rather more powerful analytical capacity than prevails in innovation studies' frameworks. Regimes as the causes of barriers to innovation are best understood by considering that they entangle a diversity of sociomaterial relations which differently bind pre-existing relations into spatial formations. Rather than working with preconceived notion of what might be, for example, 'technical', 'non-technical', 'economic', and 'regulatory' relations that cause barriers, the thesis developed an account of four main forms of barriers which are encountered as 'locking out' urban PV.'Exclusions' work through placing new technologies on the wrong side of a boundary or a threshold which must be breached or reached for realising actors' aspiration. In contrast, 'obstructions' are experienced as points of impassage through which actors must be cannot pass. Hierarchical transitivities effect 'subordinations' of the technology to other priorities such that they cannot be made material, at all or with difficulty by meeting certain criteria. Fourth, 'disconnections' are experienced as actors attempt to integrate urban PV into pre-existing practices which have traditionally not been concerned with the desirable novel features of the technology. The thesis found that the range of specific barriers to innovation in urban PV across Barcelona, London and Paris could thus be explained by considering 'lock out' as taking these four general heterogeneous qualities, which are constituted through boundaries and thresholds, impassage points, transitivities and separate realities.

This abstract conception of barriers is given life when considering that they adversely affect the creation of specific solar spaces. A material semiotic take on regimes suggests that when utopics (whatever the particular aspiration) are successful, barriers are not experienced; conversely barriers to innovation can be identified as actors' utopics come up against the relations that exclude, subordinate, obstruct and disconnect. As such, barriers 'in action' can be identified as 'locking out' very specific instances of urban PV. For instance, dense cities' 'central areas' may be excluded as prospective solar spaces owing to the slow renewal of Barcelona's aging building stock (despite a proactive planning policy) and for not catering for the energy density required by the sorts of commercial property developers operating in central London. In Paris, a city in which architectural heritage sites abound, 'planning permit sites' are characterised by a hierarchy which subordinates PV to a development logic of conservation (despite Mayoral efforts to introduce more energy-conscious principles into urban planning). Similar to the disconnection from energy-sensitive planning and construction practices of the French civil servants who enforce planning in Paris, in Barcelona the municipality's PV initiative was faced with the problem that the city's local district technical services were not familiar with PV. Obstructions in the PV's industrial supply chain long inhibited proponents' ambitions to solarise cities as these kept the price of PV up higher than reflected by otherwise decreasing manufacturing costs. Through working with a vocabulary of barriers thus outlined, Chapter 5 identified a range of solar spaces that remain utopical aspirations in the face of regimes.

Importantly, the causes of these barriers 'in action' were found to derive from four spatial forms which can be imputed in order to analyse how pre-existing relations differently integrate the range of 'locked out' solar spaces. For instance, 'networks', such as electricity infrastructures, may affect entire national territories as grid-connected spaces if incumbents exclude or obstruct access to the grid (as in the French case). 'Scales', in contrast, through integrating administrative spaces, may engender a range of barriers as different jurisdictional powers and their respective aspirations and priorities lay claim to spaces such as nations, cities, boroughs and districts. 'Places', in contrast are less administratively integrated rather than marked by an identity-based 'sense of place' which may be expressed in formalisms that exclude PV (such the Parisian 'co-visibility' radius around listed buildings) but also in more subtle ways which subordinate. 'Urban assemblages' are those constellations which operate according to particular organisational patterns, such as schools, shared ownership buildings and social housing, in which PV does not mesh easily with various rhythms of living, consuming and working. Such a spatially sensitive account provides an intricate yet parsimonious way for understanding barriers to innovation. Importantly, it does so in a way that enables one to capture the geographical contingency of innovation (as Section 7.2.5 returns to). What a material semiotic account of regimes also indicates, however, is that the conditions of possibility to innovation constituted by regimes are not static. The prospects for solar city futures are explored under in the following section.

7.2.4 The promise of solar futures

Research question 5: what are the prospects for the future of urban PV?

It should come as little of a surprise that the research suggests that the prospects for urban PV are intimately tied up with the effectiveness of utopics to resolve barriers to innovation that are caused by regimes. Chapter 5 captured this by considering how the former may effect shifts and reconfigurations in the prevailing conditions of possibility. The qualities and spatialities of regimes are not static and totalising but emergent features of the interplay between the aspirational spatialisation of utopics and the exclusions, subordinations, obstructions and disconnections caused by networked, scalar, place-based and urban assemblage relations. Some barriers may be encountered as 'persistent', as even proactive planning policies cannot change the fact that cities renew themselves only slowly, incumbents continue to exercise their reach over electricity grids and the identity politics of places remains tied into scalar jurisdictions that reproduce development logics that may, however justified, appear as anachronistic given the ecologically-orientated political imperatives of the times. However, often utopics generate a 'progressive' blurring between what is and what might be. Change becomes noticeable at particular 'points of inflection' at which qualitative shifts in the real and possible have taken place. Policies are introduced and reformed (however, pro- as well as potentially regressively), grid parity reached, PV products proliferate, and knowledge, skills, and electricity consumption and production practices – 'prosumption' (see Section 6.5) – evolve. Central to the question concerning the prospects of urban PV is therefore a question of utopics, and specifically, who engages in such aspiration-driven undertakings, what forms these take and with what effects. While leadership, critique, synergy and problem-solving are likely to remain key factors facilitating (and simultaneously constituting) urban PV, it could be argued that urban PV's future – its wider and continued implementation – may depend upon other forms of utopics to emerge.

It is precisely through constituting a utopical nexus around which aspirations for the future may be spatialised that PV's prospects take shape. These may relate to its ability of 'un-black-boxing' a range of 'unsustainabilities' that are attributed to the status quo, as explored in Chapter 6. For instance, a utopic that was not explored in this thesis, however elements of which could be identified, is one that is tied up with PV as a technique for a 'sustainable' techno-ethical mode of consumption. Evidence suggests that in some cases – for instance, of 'solar stockholders' such as 'Yolanda Delgado', and pupils of the 'solar schools' – PV becomes a part of a sustainability utopic through which actors may convert their aspirations about future forms of resource consumption into the here and now. PV's utopical multiplicity draws into focus what was in many ways the thrust behind this PhD's quest for a conceptual approach to innovation in urban PV outside of mainstream approaches in innovation studies; namely, that what precisely constitutes the 'technological' attribute of particular objects is not given within their 'intrinsic' nature or material make up. Technologies, it was argued over the course of the thesis (most expressively in Chapters 2, 4 and 6) are a means to an end. As such, a technology such as PV, along with the sociomaterial architecture of a myriad – of artefacts, texts, events and finance – that it fronts may serve different actors, in different ways, at different times. As both an outcome of, as well as a vehicle for, innovation, the prospects of solar futures are intimately tied up with PV's utopical versatility – that it may become 'utopical' for other actors, whether as a technology for eco-empowerment, carbon reduction, livelihoods, or in entirely different, novel and unanticipated ways.

7.2.5 Variation and interconnection abound

Research question 2: is there evidence of variation across different urban and national contexts?

Taking a distinctive approach to comparative analysis, this thesis found that variation and interconnection were important features of innovation in urban PV *within* and *across* the different urban and national contexts that featured empirically. A (eventual, see Section 3.1) framing of the research as ‘innovation in urban PV’, as opposed to ‘urban PV in three cities’ aligned the research with recent approaches to relational comparison (Robinson 2011; Ward 2010; Bell 2003) which suggest letting commonality and difference unfold as the research process generates these as salient aspects for analysis. As a result the thesis’ captured the emergence of a range of solar im-/possibilities taking shape at the confluence of utopics and regimes. Important differences between the empirical cases were brought to the fore in Chapter 6 which explored a range of ‘solar heterotopia’. While these share in common that they are sites in which alternatives relational to the ‘unsustainabilities’ of a status quo take shape, across empirical cases they differently enacted partially coherent solar cities. Variation emerged strongly in terms of the heterotopic sites of the urban sustainability icons, the resource city, sites of prosumption and solar schools. While the latter were entirely absent from the Parisian case, all the former differed with respect to the particular character and location of solar heterotopia. For instance, ‘sustainability icons’ differ with respect to the degree to which they are contested and who precisely engages in debates, and about what kind of (un)sustainability. The decentralised powering ‘sites of prosumption’ are characterised by a range of emerging socio-economic configurations (‘rent-a-roof’ and ‘ESCo’ models (London and Paris), Barcelonan participatory installations and London’s semi-detached domestic dwellings), while the space of the ‘resource cities’ were represented rather differently in terms of urban morphology and resource endowments across actors’ utopics. Each case draws attention to the importance of comparison for understanding innovation as emergent from the utopical efforts to change the regimes that are in place.

This raises a question concerning the instances in which variation and interconnection, respectively, become meaningful and consequential. The findings suggest that there is significant interconnection between actors’ utopics across contexts. Across cases, Chapter 4 identified three concrete aspirations to be achieved through innovation, four sets of utopical techniques which are combined into four utopics of innovation. While the content of these is shaped by what is in place, the same aspirations, architectures and ways of combining these were present across cases (and thus interpreted as constituting general features of urban PV). Differences across specific aspirations and utopics were much more significant than differences across empirical cases. For instance, eco-empowerment is explicit in targeting domestic, community and other, traditionally passive sites of consumption while as long as carbon is reduced and a sale is made carbon reduction and livelihood are much less discriminating in the sorts of spaces they seek to gather, respectively. And there are important differences in ways of intervening between 'leading by example' (and expecting others to follow suit) or seeking to unsettle taken for granted relationships to energy, actively synergising different actors' interests or providing advice for enabling others to catalyse change. While united by their aspirations to change that which prevails, a comparative perspective revealed the different principles and means according to which a desire for change is enacted.

On the other hand, variation is significant in terms of the regime relations that come to bear upon actors' utopics. While regimes effect similarly the 'lock out' of novelty across cases – through their effects, spatialities and temporalities – they integrate rather different pre-existing relations into barriers. Given that regimes are the relations which become intelligible through specific actors' utopics, their specificity is perhaps unsurprising despite being defined by four common qualities and spatialities, and three temporalities. Networks, scales, places and urban assemblages take on concrete content in the way they 'lock out' a diversity of prospective solar spaces across the empirical cases. For instance, networked geographies of powering emerge as national and regional features (France/UK and Catalonia, respectively), while inter-scalar regime effects are generated between, for instance, the national-urban (French Civil servants and urban solar sympathizers), local-urban (Barcelona's district services and London borough planners) and national-global (volatile Spanish and UK policy affecting industry demand). Places emerge as highly contingent historically bound relations (Paris' *patrimoine* and Southwark's regeneration). Urban Assemblages, while present across cities take on different concrete significance as regimes, constituted for instance by central areas (Barcelona and London) and social housing and shared ownership buildings (Paris). While regime spatialities are differently expressed across empirical cases they also involve temporally differentiated and heterogeneous qualities of 'lock out'. For instance, exclusion through a slow renewal rate of the built environment and place-based subordination to regeneration, in Barcelona and London respectively, are differently inflected by the coming into force of a mandatory planning policy. Other progressive evolutions may culminate in general inflections, such as 'grid parity', however again this changes specific possibilities in geographically different ways owing to how grid parity is a function of national electricity prices, local climate and global technology prices. On the whole, the findings suggest that in order to understand the prospects for innovation, 'sustainable' or other, questions of geography and temporality are critical. The thesis' comparative approach, characterised by a commitment to eliding the reification of narrowly construed notions of the territorial 'city' or 'the nation' yields a rich account of the varied and interconnected dynamics of innovation. While these are features that are often taken for granted rather than interrogated, this thesis thus makes a step towards developing a more intricate account of innovation's spatio-temporality, beyond the regional, sectoral or national 'system'.

7.3 Implications of the research

7.3.1 'Tools and sensibilities' rather than 'testing' and 'tuning'

The thesis develops a 'material semiotic' approach to innovation, which departs fundamentally from prevailing approaches in innovation studies. The position is informed by a trans-disciplinary strand of scholarship that has been called 'material semiotics' (Law 2007; 2008), which is informed by actor-network theory (ANT) in science and technology studies and diverse contribution from sociology, human geography, anthropology that can be taken to fall under 'post-ANT' materialist and relational thinking. Perhaps the most important departure staked by the thesis is to devise a way of responding to calls for greater scholarly reflexivity in the practice of innovation research. Such calls have originated in particular from those who straddle being *a part* of or *apart* from *SNM*/*MLP* transitions research (e.g. Genus and Coles 2008; Hommels et al. 2007b; Truffer 2008; Bulkeley et al. 2010; Hodson and Marvin 2010; Shove and Walker 2007). In an important way this thesis can be understood as making these concerns concrete around a set of kindred material semiotic notions of 'ethico-onto-epistemology' (Barad 2007) 'ontological politics' (Mol 2002), and the 'performativity of method' (Law 2003; 2004a). These suggest breaking down the separations between questions of knowing (epistemology), being (ontology) and valuing (ethics). From this perspective, scholars are necessarily themselves implicated in creating (or rather, 'enacting') particular realities of innovation and are a constitutive part of framing the material and discursive conditions for policy and practical intervention.

The original approach to researching innovation in urban photovoltaics that derives from such material semiotic sensibilities has both conceptual and methodological implications for existing innovation scholarship. Conceptually, it leads to a fundamental re-conceptualisation of several concepts that are key to innovation studies' frameworks such as the *SNM*/*MLP* framework. Whilst sharing a basic concern for understanding the role of innovation in technology for broader processes of transformation, the thesis rejects 'niches', 'regimes' and 'landscapes' (and, 'rules', 'expectations', 'networks' etc.) as entry points for inquiry. These analytical 'units' are fundamentally discarded in favour of understanding how phenomena such as technology, innovation, barriers and transformation are emergent features of particular kinds of practices – specifically, of those that seek to turn aspirations about the 'good' (whichever content this takes in practice) into actual states of affairs. Thus, rather than focusing analysis on how niches form, grow, stabilize and somehow upscale in the face of regime selection pressures and landscape trends, the material semiotics of innovation in technology of this thesis develops a relational approach that is concerned with exploring the multiple materialities, spatialities and politics of innovation in practice. A central point of departure is, therefore, that 'analytical units' are not used for explanation but rather as constituting themselves *the very questions* around which inquiry takes place.

This conceptual shift – intimately related to ethico-onto-epistemological questions – is hugely valuable in terms of freeing up inquiry into innovation beyond the restrictive (and mostly implicit) spatial, temporal, and material imaginary of the *SNM*/*MLP* model. In the first instance, it constitutes an argument about the researcher's inextricable implication in performing particular realities of innovation. Failing to concede that one is very much a part of the 'world's becoming' (Barad 2007) risks naturalising, on the one hand, the primacy of particular areas and forms of interventions – such as precisely which 'unsustainabilities' are worthy of being redressed through (which particular kinds of) policy and practical interventions. Even within scholarship and beyond there is a danger of directing inquiry and analytical focus upon some features rather than others. For instance, the suggestion (as in Geels 2010b) that systems, such as electricity infrastructures, are simply organised at particular 'scales' (of government) and 'levels' (of 'structuration') effectively questions the legitimacy of other approaches who may take other geographical units as their entry points for inquiry (e.g. Späth and Rohracher 2010; Hodson and Marvin 2009a; Seyfang and Smith 2007). On the other hand, questioning taking for granted 'analytical units' of frameworks such as *SNM*/*MLP* increases analytical sensitivity to implicit conceptions of (mostly absent or implicit) understandings of materiality, spatiality and temporality. It provides a perspective, for instance, on the narrow character of current debates – for instance, on 'rule change', 'the right' spatiality that matters for sustainable innovation, on unpicking nests of niches and regimes and making these 'fit' to different geographical imaginaries (Smith et al. 2010).

Instead, a material semiotics of innovation, as developed in Chapters 2-3 and applied over the course of Chapters 4-6, suggests that innovation scholarship can benefit substantially from grasping the empirical complexity of innovation in practice by treating features such as space, time, and agency as emergent, rather than inherent to particular spaces (e.g. nations), actors ('incumbents') or relations (e.g. niches and regimes). This acknowledgement of multiplicity is central to material semiotics. In this thesis specifically, an attention to multiplicity – of actors, spaces, times and materials – enabled the thesis to capture the complexity of the topic of innovation in urban photovoltaics. In Chapter 4, for instance, this served to explain how a variety of actors are innovating in very different ways and through different means. In Chapter 5 multiplicity was mobilized to capture the emergent heterogeneous and multiplicity of spatio-temporal regimes as the 'barriers in action' to innovation. And in Chapter 6 the transformative potential of urban PV was cast as a product of multiple intersecting utopics reconfiguring the conditions of possibility. Centrally to the thesis as a whole, a self-understanding of my research practice as itself performative of a particular reality of the topic studied, acknowledges that the very existence of the object under investigation – urban photovoltaics – is to some extent an artefact of the research itself. On the whole, the fundamental implication of material semiotics for innovation scholarship is to question the merit of forms of scholarship that are more inwardly concerned with blindly applying, 'testing' and 'fine-tuning' otherwise fully-fledged theoretical constructs in favour of academic practices that are guided by conceptual 'tools' and methodological 'sensibilities' (Law 2007) and accountable for their own ontological politics. This is particularly important considering the second implication of the research, which is that scholarship is a practice that is not different in kind from the more overtly interference-orientated domains of policy and practice.

As such, techniques, utopics, sociomaterialities are valuable concepts for introducing a more complex account of technology to that which prevails in innovation studies approaches. In the latter, technology is rarely interrogated, but rather assumed to take on particular material forms (i.e. the artefact) and social meanings (in the case of renewables energy technologies, such as PV, that they are 'green' or 'sustainable'). As a result, approaches such as *SNM*/*MLP* have tended to downplay the diversity of actors, the various roles of technologies and different modes of innovating. In contrast, the multiplicity that characterises urban PV in this chapter raises a fundamental question concerning the basis upon which something like a 'technological niche', a key 'analytical unit' in the *SNM/MLP* framework, can be drawn in the first place – e.g. aspirations, utopics, sociomaterialities? Whether or not it still make sense to do this, the *SNM/MLP*'s assumption that as expectations about technology 'converge' over time, niches will 'grow' and 'stabilise' (see Section 2.2.3) is problematic as visions of carbon control, business expansion and far-reaching social change are based on fundamentally different notions of what is 'technological'. It may be the case that that potentially numerous parallel and competing 'versions' of PV co-exist alongside one another, even within the same city.

7.3.2 The utopical scholarship-policy-practice nexus

A central implication of the research is that 'policy' and 'practice' are not only closely related to one another – most basically, from a material semiotic perspective, policy *is* practice. And so, in fact is scholarship. Or rather, all three are forms of practice that enact particular realities and thus serve to intervene in the conditions of possibility. What they share in common, in other words, is that each is concerned with 'mattering', in the ontological-political sense of 'making a difference' (e.g. Mol 2002; Law 2004). Over the course of the thesis a range of actors were introduced which can be attributed to the domain of 'policy' (as public institutional actors), or 'practice' (as non-governmental actors from the private and third, non-profit, sectors). However, it was revealed that actors as diverse as urban municipal authorities, profit-seeking solar energy companies and socio-ecological advocacy groups all operate according to the principle of 'utopics' – each is concerned with converting their aspirations for particular states of affairs of the into the 'here and now', whatever precise shape aspirations take in practice. While the research revealed that substantive differences between, for instance, visions of eco-empowerment, carbon reductions and livelihoods have important implications for innovation in urban PV, this should not detract from the common 'utopical nexus' that underlies these actors' rather different ways of innovating. This argument is applicable to the pervasive distinctions made between 'scholarship', 'policy' and 'practice'. This thesis thus concurs with interventions such as Bulkeley et al. (2005) who argue that a clear cut separation between policy and practice, in particular in terms of a linear 'implementation' process, is unhelpful as it makes it difficult to comprehend interconnection.

The thesis develops its own specific understanding of the relationship between the scholarship, policy and practice of innovation; namely that all three are concerned with bringing desirable futures forth into the present. While on this basis it is rejected that there is a clear cut a priori separation between policy and practice *as such*, it is however the case that they frequently work through different forms of utopics. For instance, as a researcher I am translating my interest and broadly supportive disposition towards PV into a PhD thesis (and a range of other outputs) that I hope will serve to inform scholarship, policy and practice (see Section 7.3.3 and 7.3.4). As such my utopics can be seen to fall under the heading of 'problem-solving' (see Section 4.4.4) which was distinguished alongside other forms of interventions in which actors 'lead' by example, offer up alternatives through 'critiquing' the status quo, forge 'synergies' or enable others by 'solving problems'. In each case different modes of intervention are tied to imaginaries of causality as well as being tied to the means available for realising utopical aspirations. While my utopical means are comparatively rather limited, others' utopics are fortunately much more effective in interfering with the prevailing conditions of possibility. The following two sections set out two key implications of the research for those seeking to foster innovation which apply to those operating at the utopical scholarship-policy-practice nexus.

7.3.3 Identifying barriers and the politics of the 'expert'

While it is a common assumption that the identification of barriers is the first step in designing interventions that will foster new technologies the research suggested that barriers become intelligible in the act of innovating itself. In this way the research draws attention to the fact that barriers are not universal experiences but are intimately tied to the experiences of innovators 'in action'. The findings of the research are that the causes of barriers to innovation in urban PV are numerous and variegated across time and space and as such there is an important spatial and temporal texture to barriers to innovation which ought to be captured by those identifying and analysing. Critically, it is only as aspirations about PV were converted into practice that it became evident how precisely that which predates novelty comes to bear upon efforts to innovate. For instance, that formal regulatory reform in existing electricity networks did not eradicate lingering obstructions that incumbents may cause in granting grid access (e.g. costs and delays); or that despite reforms of local planning systems and even mandatory renewable energy policies, new technologies remain marginalised by established urban development visions or the slow renewal rate of the built environment. As such, whoever is designated as having the capacity of knowledgeable 'expert' is best advised to inquire into innovators' on the ground experiences concerning the quality, spatiality and temporality (see Chapter 5) of barriers to innovation.

In particular, experts and analysts need to be wary of the representations they make of the 'barriers to innovation'. An important question concerns, for instance, *whose* experiences become framed as barriers while others' do not. This becomes evident when considering, for instance, the controversy over 'solar farm' developments in the UK. While this did not feature as a central theme over the course of the thesis, owing to the fact that it occurred beyond the thesis' (temporal) empirical cut off point, it is telling of how what is a promotional intervention for some may constitute a barrier for others. The UK government's aspiration to promote PV amongst 'non-traditional generators' (DECC 2009) – i.e. at the sub-utility scale – translates into a barrier for solar energy companies who are seeking to secure a livelihood and profits through selling their products, regardless of who uses them. On the other hand, government understand solar farms as not compatible with its broader vision of solar power and views large-scale generation as leading to the exclusion of the main target group of the policy. How barriers are framed in this case differs according to the party involved – importantly, this signals that the role of the expert is not that of a neutral observer and analyst but is performative of particular technological realities. From an ethico-onto-epistemology characteristic of material semiotics this is a fact that needs to be accounted for.

7.3.4 The substances of innovation

That different visions of the directions and content of innovation may exist is a finding of the research that has another important implication for fostering innovation. The findings show that differences may lead to conflict as well as synergies. It was found that there are important ways in which innovators forge mutually beneficial alliances (see Section 4.4.3). For instance, on the back of market support tools such as feed-in tariffs several new business models are emerging that in their different forms contribute to the consolidation of a broader base of solar generators in cities and beyond. Whatever the precise benefits to end users of 'rent-a roof' schemes and 'Energy Services Companies' (see Section 6.5), findings suggest that financial incentives alone may be ineffectual in the absence of other materials, as the case of Spanish feed-in tariff illustrates (see Section 5.4.2). Critically, this alerts to the importance of a range of material 'substances' of innovation. Financial means, while sometimes treated as the primary vehicle for fostering new technologies, emerge as one of several important pivots around which otherwise unconcerned actors may become involved with new technologies; whether in the capacity of ‘adopter’, corporate sponsors, partner, or other. Diverse substances, or ‘architectures’, of innovation serve as important hinges for linking up the unconnected; they are *the very means* through which innovation takes place.

Concretely, the research points towards the importance of a range of architectures that make material differences in innovative processes. While ‘finance’ is likely to be available as an instrument only to the institutionally powerful and well-resourced actors, such as national governments and large corporations, evidence suggests that the role of a range of ‘artefacts’, ‘events’ and ‘texts’ should not be underestimated. For instance, well-positioned artefacts, such as on schools and ‘flagship’ technology installations, monitors and displays are potentially powerful tangible nexuses giving new meanings to urban spaces through providing the means for raising civil consciousness about climate change and energy consumption practices (e.g. Sections 4.3.1, 6.2, 6.3, 6.6). Events serve as important forums for networking, debate, information and even celebration. They enabled one non-profit to push down the price of their own PV product (*Fundación Tierra*’s solar guerrilla panel); the Parisian public to debate about future urban development; and a range of national, European and global industry protagonists to compete and forge synergies at annual technology showcases. Findings also suggest that policy documents, technical and advocacy reports are just some of the texts that represent particular knowledges and realities, they formally enshrine strategic policy commitments, justify intervention and interrogate the limits of – technical, political – possibilities. The implication is that whichever technique is to serve as a pivot for engaging actors this needs to be carefully articulated and positioned in order to produce the desired result. Critically, as creative and effective campaigns such as Barcelona-based *Fundación Tierra’s* Solar Guerrilla’ and London-based *Solarcentury’s* ‘Solar4schools’ suggests, different architectures complement one another through the range and diversity of relations they each assemble. As such, through carefully designing how finance, artefacts, events and texts might be applied in concert, there is scope for well thought-out forms of intervention to take shape.

7.4 Limitations and future avenues of research

Perhaps the most far-reaching consequence of applying material semiotic principles to the study of technological innovation is related to the recognition that the reality of innovation is multiple, constituted by numerous, even a myriad, of different practices of intervening and strategically or passively reproducing prevailing relations. While this no doubt constitutes a key strength of the approach it is also a feature of material semiotics that is problematic – there is a constant danger that complexity spirals beyond the confines of what is manageable. At times this was certainly the case with the present thesis; and perhaps it was particularly pronounced given the experimental nature of translating the implications of a material semiotic position into research practice. Here the first avenue of future research takes shape: the issue of spiralling complexity constitutes a real methodological challenge which could fruitfully inform future avenues of research. For instance, as was the case with actor-network theory in the 1980s and 1990s, it may be possible to suggest general guidelines for juxtaposing different evidence sources according to a 'symmetry principle' akin to the principle of generalised symmetry proposed by Callon (1986b); and here emerging developments in data analysis software packages may prove valuable accomplices. However, care should be taken to not replace computational sophistication with the 'canniness' of the researcher (Austrin and Farnsworth 2005), as it should be kept in mind that methods do not so much uncover as opposed to perform particular (sociomaterial-) realities.

This brings me to the second point which may limit the benefits of a material semiotic methodology such as proposed in this thesis. The realities of 'policy' and 'practice' remain such that, not only *are* these domains marked by a separation of people, spaces and means for intervention; it is also the case that they have their own modes of operating which generally rely on simplicity and parsimony often to the detriment of detail and complexity. Policymaking by definition involves trade-offs and the weighing up of different 'goods' – and, as I experienced myself, often prides itself on relying on 'objective' advice from 'specialists' and 'experts' for formulating policy directions and interventions. Towards the end of my time as a PhD researcher I was involved in drafting a background policy briefing on the prospects of PV in the UK (in light of recent reforms that had been the source of a substantial amount of controversy). Here there is little space for exploring different 'sociomaterialities' or 'utopics'. Literally, *space* – in less than 3,500 words the document is required to inform a 'busy, educated but lay' audience of parliamentarians in an 'objective' manner of all sides and aspects of the debate *that are of* *relevance*. Wary of my performative effect upon the latter, I found that this was not an easy task at all. I faced a similar situation when I was asked to present to an audience of 'practitioners' (industry representatives, academic and independent researchers, PV installers and other small scale solar businesses such as roofers) by the PhD's public sector sponsors (the *County Durham Development Company*). As with the policy briefing, this required a different language and emphasis in which nothing but some – limited – *implications* of relationality, materiality, multiplicity, and performativity were present (and certainly not phrased in these terms). As such, while the compatibility between material semiotic research and technology policy and practice remains open to question, here a future avenue for research emerges; concerning the ways in which – and indeed the merits, if there are any – of material semiotics for assisting, informing, and guiding the utopics involved in 'policy' and 'practice'.

While such an inquiry may well find that material semiotics has little to add to these domains, I will conclude this thesis by proposing two ways in which it could. In the first instance, other scholars similarly sensitive to questions of materiality (e.g. Lovell 2005; Hobson 2006; Keirstead 2006; Shove 2003) have already begun to ask about the importance that materials have in reconfiguring 'unsustainabilities'. Hobson (2006), for instance, develops a sort of 'techno-ethics' around shower timers, and similarly Elizabeth Shove and Gordon Walker (2010) suggest that a focus on everyday practices (of room temperatures, working times etc) feature as key components in creating 'unsustainabilities'. Chapter 6 made an exploratory step towards such an understanding of the role of PV and other materials beyond the immediate PV system (display monitors, educational materials and tools of knowledge creation) – however much more can be made of this. Second, when it comes to searching for more sustainable futures, the material semiotic sensitivity to multiplicity – of voices and sociomaterial realities – could fruitfully translate into a concern for enfranchising those which are frequently spoken *for* by others. Here there is a sensibility of 'giving voice' to alternative accounts and silent others which is in some ways kindred to participatory methodologies that have been promoted by a range of scholars in recent years (e.g. Alexander et al. 2007; Pain and Kindon 2007; Pain et al. 2011). In fact, these could offer a potential methodological basis for a material semiotic methodology in which the performativity of method is harnessed for the purpose of the sort of interventionist scholarship that several key material semiotic scholars (e.g. Mol 2002; Verran 2001; Law 2004) frequently call for.

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Appendix A: data sources I: documents

General

ID#	Author	Publication date	Type	Format	Name
G1	EPIA	01/05/2010	Report	pdf	*Global market outlook for photovoltaics until 2014*
G2	EPIA	01/01/2008	Report	pdf	*Global Market Outlook for Photovoltaics until 2012: Facing a sunny future*
G3	EPIA/ Greenpeace International	01/01/2011	Report	pdf	*Solar Generation 6: Solar Photovoltaic Electricity Empowering the World*
G4	Euractiv	22/04/2010	website	html	*Lobby chief wants to open 'new chapter' for solar PV*
G5	Euractiv	16/05/2008	website	html	*Solar on the Rise, Despite 'Enemies'. Interview: Ernesto Macias Galán, Vice President of Epia.*
G6	Hoffman, W	01/01/2006	Article	pdf	*Photovoltaics on the Way from a Few Lead Markets to a World Market. European Renewable Energy Review 2: 31-34.*
G7	IEA	06/12/2007	Presentation	pdf/ppt	*IEA Task 10 - Urban-Scale PV Applications PV Power Systems. Presentation at PVSEC-17 Fukuoka, Japan. by Christy Herig.*
G8	IEA	01/06/2004	Presentation	ppt	*PV Power Systems, Task 10 – Urban Scale Pv International Energy Agency ETA Stakeholders Workshop. Florence, Italy. by Christy Herig*
G9	JRC	01/01/2010	Report	pdf	*PV Status Report: Research, Solar Cell Production and Market Implementation of Photovoltaics*
G10	New Scientist	08/01/2007	Press	hard copy	*New Scientist. Here Comes the Sun: our solar powered future.*
G11	OECD/IEA	01/01/2000	Report	pdf	*Experience Curves for Energy Technology Policy*
G12	Renewables International	04/10/2010	Promotional	pdf	*Solar Atlas: Solar Roofs for Berlin.*
G13	S&WE	01/01/2010	Press	hard copy	*Hyundai Solar. Imagine: How a Single Solar Module Can Save a Polar Bears Home. [Advertisement]*
G14	S&WE	01/04/2008	Press	hard copy	*Sun &Wind Energy. International Issue 04/2008*
G15	UNEP	01/01/2008	Report	pdf	*Green Jobs Report*
G16	virtualcitySYSTEMS	01/01/2008	Guidance	pdf	*Case Study: Solar Atlas Berlin. Lidar Solar Analyses. by T. Woge.*

Barcelona

ID#	Author	Publication date	Type	For-mat	Source name
B1	AEB		Guidance	html	*L'Energia Solar Fotovoltaica*
B2	AEB		Leaflet	pdf	*Fitxa: Les Energies Renovables*
B3	AEB	21/02/2007	Presentation	ppt	*Estratègies per a l'energia solar fotovoltaica a Barcelona: Primeres Jornades Universitat-Empresa: El repte energetic. Barcelona (Ruyet, David, Director Tècnic de projectes)*
B4	AEB	20/06/2007	Presentation	ppt	*Implantación de la energía solar fotovoltaica en Barcelona (Miguel Miguel)*
B5	AEB	27/06/2005	Report	pdf	*El comptador : informació energètica de Barcelona. N. 1 (2005)*
B6	AEB		Strategy	pdf	*Barcelona Energy Agency: Towards a New Energy Culture*
B7	AEB/ Ajuntament de Barcelona	29/06/1905	Guidance	pdf	*Repensar Barcelona amb la nova cultura de l'energia: Un compromís, totes les oportunitats*
B8	AEB/ Ajuntament de Barcelona	25/01/07	Press	pdf	*Instal·lació de Centrals Fotovoltaiques en equipaments municipals de la Ciutat de Barcelona*

B9	AEB/ Ajuntament de Barcelona	23/02/2006	Press	pdf	*Instalación decentrales fotovoltaicas en equipamientos municpales de Cuidad de Barcelona*
B10	AEB/ Ajuntament de Barcelona	01/03/2003	Press	pdf	*Fitxes de les 8 escoles: Instal·lacions fotovoltaiques en escoles de Barcelona*
B11	AEB/ Ajuntament de Barcelona	01/11/2005	Report	pdf	*Observatory de l'Energia de Barcelona Balanç 1999 – 2003*
B12	AEB/ Ajuntament de Barcelona	30/06/1905	Report	pdf	*El comptador : Energia i canvi climàtic a Barcelona*
B13	AEB/ Ajuntament de Barcelona	01/03/2009	Strategy	pdf	*Pla d'Energia, Canvi climàtic i Qualitat atmosfèrica de Barcelona 2010-2020Concepte inicial Barcelona*
B14	Ajuntament de Barcelona	24/06/1905	Guidance	pdf	*Agenda 21: Ajuntament + sostenible*
B15	Ajuntament de Barcelona		Guidance	pdf	*Ahorro energético y energías renovables*
B16	Ajuntament de Barcelona		Guidance	pdf	*Posem verdes les associacions: Guies d'educació ambiental*
B17	Ajuntament de Barcelona	01/01/2001	Leaflet	pdf	*Instal·lació solar fotovoltaica al CEIP Font den Fargas*
B18	Ajuntament de Barcelona	22/06/1905	Leaflet	pdf	*Instal·lacions fotovoltaiques a l'edifici 'Nou' de l'Ajuntament de Barcelona*
B19	Ajuntament de Barcelona	20/06/1905	Leaflet	pdf	*Primera instal·lació fotovoltaica connectada a la xarxa acollint-se al RD 2818/1998*
B20	Ajuntament de Barcelona	01/04/2006	Policy	pdf	*Ordenanza Municpal de los Usos del Paisaje Urbana de la Ciudad de Barcelona*
B21	Ajuntament de Barcelona	18/11/2009	Press	pdf	*Barcelona regulará la instalación de centrales solares fotovoltaicas*
B22	Ajuntament de Barcelona	01/10/2008	Strategy	pdf	*Programa d'Actuació Municipal (PAM) 2008-2011. Àrea de Medi ambient*
B23	Ajuntament de Barcelona	15/10/2007	Strategy	pdf	*Programa d'Actuació Municipal (PAM) 2008-2011. Àrea de Medi ambient Document de treball. 15 octubre 2007*
B24	Ajuntament de Barcelona, Consell Municipal de Medi Ambient i Sostenibilidad	01/12/2002	Guidance	pdf	*Acción 21. Guía Metodológica para avanzar hacia la sostenibilidad de Barcelona*
B25	Ajuntament de Barcelona, Consell Municipal de Medi Ambient i Sostenibilidad	01/05/2002	Strategy	pdf	*The People's Commitment towards Sustainability. Municipal Council on the Environment and Sustainability*
B26	Ajuntament de Barcelona/Barcelona Regional	01/06/2002	Strategy	pdf	*Pla de Millora Energètica de Barcelona*
B27	Ajuntament de Barcelona/Barcelona Regional	01/06/2002	Strategy	pdf	*Plan de Mejora Energética de Barcelona (Resumen)*
B28	Ajuntament de Barcelona/Barcelona Regional	01/06/2002	Strategy	pdf	*Plan for Energy Improvement in Barcelona*
B29	Ajuntament de Barcelona/Ecologistes en Acció (Catalunya)		Guidance	pdf	*Guies d'educació ambiental 13: Guia per a l'estalvi energètic*
B30	Ajuntamient de Barcelona	24/06/1905	Strategy	pdf	*Progressant cap a una nova cultura energètica (con Generalitat de Catalunya, Àrea Metropolitana de Barcelona (Entitat del Medi Ambient), IDAE (Instituto para la Diversificación y Ahorro de la Energía), Universitat Autònoma de Barcelona, Universitat Politècnica de Catalunya)*
B31	Anta, Javier (Presidente ASIF)	11/07/2009	Press	pdf	*"Propondremos al Gobierno una ley para la energía solar" (in El Economista)*
B32	Anta, Javier (Presidente ASIF)	01/11/2008	Press	pdf	*El Real Decreto 1578/2008, Con perspectiva (in Energías Renovables, Nov 2008, p 46)*
B33	Anta, Javier (Presidente ASIF)	11/06/2009	Press	pdf	*España, primer mercado fotovoltaico (in Cinco Dias)*
B34	Anta, Javier (Presidente ASIF)	15/10/2008	Press	pdf	*Fotovotlaica con respiración asistida (in El Economista)*

B35	Anta, Javier (Presidente ASIF)	16/12/2008	Press	pdf	*La fotovoltaica va a tener una importante presencia en los edificios españoles durante los próximos años (in Correo de la Construccion)*
B36	Anta, Javier (Presidente ASIF)	29/09/2009	Press	pdf	*Un año de parálisis fotovoltaica (in El Economista)*
B37	Anta, Javier (Presidente ASIF)	01/04/2008	Press	pdf	*Una tarifa fotovoltaica flexible (in Energia Empresa)*
B38	Anta, Javier (Presidente ASIF)	01/07/2009	Report	pdf	*ASIF informa: El fundamentalismo energetic (in ERA SOLAR 151 Julio/Agosto 2009 96-97)*
B39	ASIF (Asociación de Industria Fotovoltaica)	01/05/2009	Press	pdf	*Portrait: BP (Anta, J. in ASIF informa, ERA SOLAR 150 Mayo/Junio 2009 106)*
B40	ASIF (Asociación de Industria Fotovoltaica)	01/07/1905	Report	pdf	*ASIF informa: Hacia la Consolidación de la Energía solar fotovoltaica en España (INFORME ANUAL 2009)*
B41	ASIF (Asociación de Industria Fotovoltaica)	30/06/1905	Report	pdf	*ASIF informa: Hacia un suministro sostenible de electricidad de la energía solar fotovoltaica en España (INFORME ANUAL 2008)*
B42	ASIF (Asociación de Industria Fotovoltaica)	01/10/2004	Report	pdf	*ASIF informa: Hacia una electricidad para todos (INFORME ANUAL 2004)*
B43	ASIF (Asociación de Industria Fotovoltaica)	01/10/2005	Report	pdf	*ASIF informa: Hacia una electricidad respetuosa con el medio ambiente ((INFORME ANUAL 2005)*
B44	ASIF (Asociación de Industria Fotovoltaica)	01/10/2006	Report	pdf	*ASIF informa: Hacia una generación eléctrica competitiva*
B45	ASIF (Asociación de Industria Fotovoltaica)	01/10/2002	Report	pdf	*Desarrollo de la Electricidad Solar Fotovoltaica en España*
B46	ASIF (Asociación de Industria Fotovoltaica) /KPMG	01/07/1905	Report	pdf	*Informe estratégico para el sector fotovoltaico en España: acercándonos a la paridad de red Resumen del informe realizado por KPMG para la Asociación de la Industria Fotovoltaica (ASIF)*
B47	ASIF (Asociación de Industria Fotovoltaica)/APPA	01/11/2007	Report	pdf	*El papel de la generación fotovoltaica en España - NOVIEMBRE 2007-*
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B49	Casanovas, Xavier (Professor de la Universitat Politècnica de Catalunya)	01/09/2007	Report	pdf	*L'energia solar a Barcelona: L'ordenança solar tèrmica*
B50	Castiella, Txema & Franquesa, Teresa	01/04/2003	Strategy	pdf	*La Agenda 21 de Barcelona: Un Proceso Participative por el Cambio, Abril 2003*
B51	Collado, Eduardo (Director técnico de ASIF)	01/01/2008	Press	pdf	*Nuevos perfiles de negocio fotovoltaico (in Energia Solar enero-febrero 2008)*
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L3	BERR	01/06/2008	Policy	pdf	*UK RENEWABLE ENERGY STRATEGY Consultation. JUNE 2008*
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L6	BERR	01/07/2008	Statistics	database	*UK ENERGY IN BRIEF JULY 2008. A NATIONAL STATISTICS PUBLICATION*
L7	BERR/EST	01/07/2007	Report	pdf	*The Major PV Demonstration Programme Final report 2002-2007*
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L80	LB Merton	01/06/2008	Policy	pdf	*London Borough of Merton: Climate Change Strategy June 2008*
L81	LB Newham	28/06/2005	Report	pdf	*COUNCIL'S ROLE IN PREVENTING CLIMATE CHANGE SCRUTINY COMMISSION FINAL REPORT COUNCILLOR WINSTON VAUGHAN (CHAIR)*
L82	LB of Camden	01/01/2006	Policy	pdf	*Climate Change in Camden - A Joint Effort Camden's Climate Change Action Plan 2006 – 2009*
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L99	LEP/Mayor		Leaflet	pdf	*Energy Action Areas working towards low carbon developments*
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L185	Solar Century	13/12/2007	Leaflet	pdf	*London Fire & Emergency Planning Authority*
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P2	ADEME	01/06/2008	Promotional	hard copy	*La production d'électricité raccordée au réseau*
P3	ADEME	01/03/2009	Promotional	hard copy	*Les aides financières habitat*
P4	ADEME	01/10/2004	Promotional	pdf	*Intégration des cellules photovoltaïques : une réussite architecturale à l'Hôtel Ibis, porte de Clichy*
P5	ADEME	01/10/2007	Technical literature	pdf	*Guides et cahiers techniques : Photovoltaïque intégré au bâti, Quelques exemples*
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P75	Mairie de Paris	01/07/2007	Audit	pdf	*Le bilan carbone de paris. Bilan des émissions de gaz à effet de serre*
P76	Mairie de Paris	01/10/2008	Leaflet	pdf	*Les Avantages des Panneaux solaires*
P77	Mairie de Paris		Report	pdf	*Les Propositions de l'Observatoire de la Ville « Peut-on faire du développement durable un levier d'attractivité pour la Région Capitale ? »*
P78	Mairie de Paris		Report	pdf	*PADD/PLU : 1ere partie Améliorer durablement le cadre de vie quotidien de tous les Parisiens.*
P79	Mairie de Paris	01/02/2009	Consulation	pdf	*Plan Local d'Urbanisme. Enquête publique en vue d'une modification du PLU du 15 décembre 2008 au 2 février 2009 inclus*
P80	Mairie de Paris	01/06/2009	Conslutation report	pdf	*Ville de Paris Plan Local d'Urbanisme ENQUÊTE PUBLIQUE RELATIVE A LA MODIFICATION DU PLAN LOCAL d'URBANISME RAPPORT D'ENQUÊTE (Dossier N° E08000017/75)*
P81	Mairie de Paris	30/06/1905	Policy reform	pdf	*Objet : Avis sur l'engagement par le Maire d'une procédure de modification du Plan local d'urbanisme de Paris. PROJET DE DELIBERATION EXPOSE DES MOTIFS*
P82	Mairie de Paris	2006 ?	Consulatation report	pdf	*CONSULTATION SUR LE PLAN LOCAL D'URBANISME CONSTRUIRE AVEC VOUS L'AVENIR DE PARIS*
P83	Mairie de Paris	01/07/1905	Policy	pdf	*RAPPORT DE PRESENTATION DE LA MODIFICATION DU PLU*
P84	Mairie de Paris	13/12/2010	website	pdf	*Installation de panneaux solaires*
P85	Mairie de Paris		website	pdf	*Plan Local d'Urbanisme*
P86	Mairie de Paris	29/06/1905	Policy Plan	pdf	*Plan Climat (version anglaise) PARIS CLIMATE PROTECTION PLAN*
P87	Mairie de Paris		Working document	pdf	*Cahier du PLU no. 2: Synthese du groupe Environnement: Éléments pour une première synthèse des travaux d'élaboration du diagnostic préalable au projet de plan local d'urbanisme de Paris (groupe Environnement et développement durable)*
P88	Mairie de Paris/ADEME	01/07/2008	Leaflet	pdf	*Copropriété Objectic Climat*
P89	Mairie de Paris/CAUE	01/10/2008	Leaflet	pdf	*Panneaux solaires (FICHE THÉMATIQUE Cahier de Recommandations Environnementales)*
P90	Ministère de L'Écologie, du Développement et de L'Aménagement Durables	01/02/2008	Report	pdf	*RAPPORT: Le Programme de Recherche et d'Expérimentation sur l'Energie dans le Bâtiment (PREBAT)*
P91	Ministère de l'Économie, des Finances et de l'Industrie	28/06/1905	Report	pdf	*Technologies clés 2010*
P92	Ministère de la recherche, Direction de la technologie	01/02/2005	Policy	pdf	*NOUVELLES TECHNOLOGIES DE L'ENERGIE: PROPOSITION DE PROGRAMME DE RECHERCHE*
P93	Ministère de l'économie, des finances et de	01/11/2003	Policy	pdf	*Livre blanc sur les énergies.*

	l'industrie				
P94	Observ'ER	01/05/2009	Guidance	pdf	*Le Crédit d'impôt*
P95	Poignant, Serge	16/07/2009	Report	pdf	*Rapport D'information Déposé En Application De L'article 145 Du Règlement Par La Commission Des Affaires Économiques Sur L'énergie Photovoltaïque Paris, Assemblée Nationale*
P96	Poniatowski, L	01/01/2011	Report	pdf	*Quel Avenir Pour La Filière Photovoltaïque Française? Rapport D'information N° 442 Fait Au Nom De La Commission De L'économie, Du Développement Durable Et De L'aménagement Du Territoire. Paris, Sénat Session Ordinaire De 2010-2011*
P97	SER/ADEME	02/07/2007	Guidance	pdf	*Guide des producteurs d'électricité d'origine photovoltaïque*
P98	Soler/SER	02/09/2008	Presentation	ppt	*Development of Leading European Markets - Policy up-date. 2 September 2008. SOLER, French photovoltaic professional group (by Elamine Wael, Photovoltaic officer)*
P99	Sun and Wind Energy Magazine	01/04/2008	Press	hard copy	*EDF's realm of shadows (S&WE 4/2008: 148-149)*
P100	Sun and Wind Energy Magazine	01/04/2008	Press	hard copy	*Solar Power Becomes "en vogue" in France (S&WE 4/2008: 40-43)*
P101	Sun and Wind Energy Magazine	01/06/2009	Press	hard copy	*Stranger in a nuclear country (S&WE 06/2009: 108-109)*
P102	Sun and Wind Energy Magazine	01/09/2010	Press	hard copy	*Six weeks in Germany, 39 in France (S&WE 09/2010: 206-209)*
P103	SER	01/07/2009	Promotional	pdf	*Présentation de QualiPV, label qualité des installations photovoltaique pour le secteur résidentiel*
P104	SER	01/06/2009	Guidance	pdf	*10 fausses vérités sur le photovoltaique - Plateforme européenne du photovoltaïque Qu'est ce que le photovoltaïque et quelles sont ses domaines d'application? PHOTOVOLTAÏQUE : LES FAITS Plateforme Européenne de l'Industrie Photovoltaïque http://www.enr.fr/docs/2009011449_fichephotovoltaique.pdf*
P105	SER	28/05/2009	Guidance	pdf	*Solaire photovoltaïque : vers la maison de l'avenir*
P106	SER	01/03/2009	Guidance	pdf	*Les énergies renouvelables dans les codes de la construction et de l'urbanisme*
P107	SER	07/04/2011	Guidance	pdf	*Etat des lieux du parc photovoltaïque français Bilan de l'année 2010*
P108	SER	23/07/2010	Guidance	pdf	*PV Kit communication 2010*
P109	SER	23/07/2010	Guidance	pdf	*Fiche PV France*
P110	SER	23/07/2010	Guidance	pdf	*Fiche PV technologies*
P111	SER	23/07/2010	Guidance	pdf	*Fiche PV applications*
P112	SER	23/07/2010	Guidance	pdf	*Fiche PV bâtiment*
P113	SER	01/07/2010	Article	pdf	*Propositions pour assurer un essor durable de la filière solaire photovoltaïque en France*
P114	SER	01/07/2009	Guidance	pdf	*Obligation d'achat photovoltaïque : les questions que vous vous posez - EDF-AOA*
P115	SER	01/07/2009	Datanase	pdf	*Baromètre photovoltaïque 2008 - EurObserv'ER*
P116	vie-publique.fr, un site de la Direction de l'information légale et administrative			pdf	*LES ABF, ARCHITECTES OU URBANISTES ?*

Appendix B: data sources II: interviews

Barcelona

Organisation name	Organisation type	Date	Interviewee	Interview type
Agència d'Energia de Barcelona	Municipal energy agency	11/03/2009	Engineer 1, Engineer 2	Face to face
Agència d'Ecologia Urbana de Barcelona	Non-profit	10/03/2009	Director	Telephone
Barcelona Regional	Public-Private	23/04/2009	Senior Project Manager	Questions via email
Diputació de Barcelona, Oficina Tècnica de Canvi Climàtic i Sostenibilitat Gerència de Serveis del Medi Ambient (Oficina Tècnica de Canvi Climàtic i Sostenibilitat Gerència de Serveis del Medi Ambient)	Public	16/03/2009	Energy Advisor 1, Energy Advisor 2	Face to face
Ecoserveis	Non-profit	13/03/2009	Energy Advisor	Face to face
Fundación Tierra	Non-profit	09/03/2009	President	Face to face
Greenpeace (Catalunya)	Non-profit	17/03/2009	Liaison Officer	Face to face
Puig i Boix, Josep	Individual	05/03/2009	Solar expert, academic, activist, President of Spanish arm of EUROSOLAR and Vice President of EUROSOLAR	Face to face
Xarxa de Ciutats I Pobles cap a la Sostenibilitat (Red de pueblos y ciudades por la sostenibilidad)	Network partnership	16/03/2009	Coordinator	Face to face

London

Organisation name	Organisation type	Date	Interviewee	Interview type
BERR, Renewable Energy Innovation Unit	Public	12/11/2008	Policy Adviser	Face to face
Buro Happold	Private	11/11/2008	Engineering Consultant	Face to face
Carbon Descent	Non-profit	13/11/2008	Managing Director	Face to face
Creative Environmental Networks	Non-profit	19/11/2008	Energy Advisor	Face to face
EST (Energy Savings Trust)	Non-profit	10/11/2008	Renewables	Face to

			Development Manager	face
IT Power	Private	01/12/2008	Project Engineer	Face to face
Jestico Whiles (Architects)	Private	18/11/2008	Architect 1, Architect 2	Face to face
London Climate Change Agency (LCCA)	Public-private	20/11/2008	Engineer	Face to face
Professor Pearsall, Nicola (Northumbria University)	Academic	18/12/2008	Academic	Face to face
Solar Century	Private	18/11/2008	Solar for Schools Manager	Face to face
Solarbuzz	Private	12/11/2008	Vice President	Face to face
UKBCSE (UK Business Council for Sustainable Energy)	Industry association	14/112008	Head of Policy	Face to face

Paris

Organisation name	Organisation type	Date	Interviewee	Interview type
ARENE Ile de France	Public	17/06/2009	Policy analyst	Questions via email
CFI (Centre des Formations Industrielles, Gambetta)	Public	16/05/2009	PV expert	Face to face
CLER (Comité de Liaison Energies Renouvelables)	Non-profit	15/06/2009	Director	Face to face
EDIF (Energie Durable en Ile de France, Espace Info Energie 10/11/19ieme)	Non-profit	05/06/2009	Energy Advisor 1, Energy Advisor 2	Face to face
HESPUL (énergies renouvelables & efficacité énergétique)	Non-profit	20/05/2009	General Manager	Questions via email
HESPUL (énergies renouvelables & efficacité énergétique)	Non-profit	29/05/2009	PV Unit Manager	Questions via email
IDEMU (Institut de l'Ecologie en Milieu Urbain, Espace Info Energie 4/5/6/7/11/12/13/14/15/20ieme)	Non-profit	27/05/2009	Energy Advisor 1, Energy Advisor 2	Face to face
Mairie du 20ieme arrondissement (local Mayor Office)	Public	30/10/2009	Project Manager, Sustainable Development and Agenda 21	Questions via email
MVE (Montreuil-Vincennes Energie)	Non-profit	08/06/2009	Energy Advisor	Questions via email
PASU (Pôle Accueil et Service a l'Usager, Direction de l'Urbanisme, Mairie de Paris)	Public	08/06/2009	Energy Advisor	Face to face
Baupin, Denis	Public		Adjoint au Maire de la	Event

			Ville de Paris	Q&A session

Appendix C: sample interview contact email

From: Anne-Christine S. Maassen [mailto:a.s.maassen@durham.ac.uk]
Sent: 27 October 2008 15:41
To: [redacted]
Subject: Interview Request for PV research project

Dear [redacted],

I am a doctoral researcher at the University of Durham, currently undertaking research on the integration of solar photovoltaic technologies into European cities.

The aim of this research project is to develop a comparative understanding of the factors shaping the development of microgeneration technologies, in particular solar PV, to provide some insights into the processes underlying and driving technological change in the field of urban renewable energy. Over the course of the next year I will be working on three case studies - London, Barcelona and Paris.

I will be conducting field research in London from 3rd November until 28th November 2008 where I hope to interview several people in key organisations that are strategic to the deployment of microgeneration technologies in London - such as [redacted]. Of particular interest to me is t[redacted], and the Low Carbon Buildings Programme more generally.

I was hoping to arrange an approx. hour-long meeting at your convenience to find out more about your work in London. I appreciate that as a busy organisation you have many competing demands on your time and I am grateful for your time and assistance with this research.

I have attached a brief outline of the project for your information, and I look forward to hearing from you. Also, feel free to circulate the details of this research project to any interested parties. Within this project there is scope for eventually sharing some key research findings with you.

Best wishes,

Anne Maassen

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Anne Maassen
PhD Researcher
Department of Geography
University of Durham
Science Site, South Road
Durham, DH1 3LE, UK

Appendix D: consent form

Durham University

Institute of Hazard and Risk Research

Solar Cities in Europe – embedding photovoltaic technology in Europe

The University of Durham attaches high priority to the ethical conduct of research. Your signature confirms that you are happy to participate in the study.

- I agree to take part in this research which is to investigate the uptake of renewable energy technologies in London.
- My contribution to the research will take the form of an interview, which will be recorded and kept securely.
- I understand that any confidential information will be seen only by the researchers and will not be revealed to anyone else.
- I have had the principles and the procedure explained to me and I understand the principles and procedures fully.
- I understand that the results of this project will be published in the form of reports, conference papers, journal articles and other academic outputs, although all data provided by myself and other participants will be anonymised as much as possible.
- I may request a copy of my interview, which will be sent in the shape of a transcript. I can make changes if I want, and advise of anything else to be done to protect my privacy.
- I understand that I am free to withdraw from the investigation at any time.

The findings of the research will be written up as feedback for you, policy makers and for other organisations interested in our work. The findings will be published, and they may also be used for teaching and research training. The written work may include quotations from interviews, but individuals will never be named, except by their position.

I confirm that I understand the points above and agree to participate in this research project.

Name (please print): ____

Signed: ____

Date: ____________________________

Appendix E: original research proposal

[Authors: Harriet Bulkeley and Karen Bickerstaff]

The Durham University Sanyo Studentship

Solar Cities in Europe: embedding photovoltaics

Aim: To understand the social and technical factors which are shaping the development of solar photovoltaic (PV) technologies in European cities.

Background

Over the past five years, driven by concerns for global climatic change and energy security, governments across Europe have become increasingly interested in the development of renewable energy technologies. PVs are perhaps the most suitable of all renewable energy technologies for widespread use in urban environments, although their uptake is patchy and currently small in scale. The extent to which PV technologies have become embedded in urban areas across Europe varies from country to country, but also from place to place. Various different programmes, including the EU-funded RESTART (Renewable Energy Strategies and Technology Applications for Regenerating Towns) and Zero-Emissions Neighbourhoods, and national initiatives such as the Italian 'PV roofs' programme, the "50 Solar Settlements in North Rhine Westphalia", and the UK's new Low Carbon Buildings Programme, have sought to encourage the development of PV technologies at the urban scale. Cities are crucial arenas for addressing environmental and energy issues (Bulkeley and Betsill 2003), and provide the arena within which many PV demonstration projects are implemented. This project will focus on the urban scale as a means for understanding the social and technical factors which enable and impede the development of PV technologies within Europe.

Current understanding suggests that the relatively low uptake of PV technologies can be attributed to costs, a lack of technical know-how amongst the building industry, the challenges of grid integration, insurance risk, and problems of design and planning permission. Research into other aspects of urban sustainability suggest that in addition the role of individual policy entrepreneurs, other key actors – including those in the community and private sectors – may also influence the take up and embedding of renewable energy technologies. Work in the field of Science and Technology Studies also alerts us to the role of producers as well as consumers in shaping the take up and use of technologies.

In order to draw together the importance of the social and technical factors in shaping the development of PV technologies within cities, this project will draw on the concept of *socio-technical systems* (Bijker and Law, 1992). Although it has not yet been applied to renewable energy, the concept of socio-technical systems has been used to examine the complex interplay between social and technical factors influencing change in the energy system (Graham and Marvin 2001; Guy et al. 1997; Guy and Shove 2000; Lovell 2005; Shove 1997; Shove 1999). Understanding how both social and technical factors shape the development of PV technologies at the urban scale will assist in extending the uptake and the creation of different PV technologies as well as contributing to theoretical advances by seeking to develop a framework for understanding urban environmental change as simultaneously social and technical.

Approach

Within this context, and in order to address the overall aim, the project will focus on the following research questions:

1. What evidence is there that PV technologies are becoming embedded within cities across Europe?
2. What factors explain the variation in the uptake of PV technologies between different countries?
3. What factors have facilitated the development of PV technologies within particular cities? How and have PV technologies become 'normalised' and embedded in policy and practice?
4. What factors have impeded the development of PV technologies within particular cities? Is there evidence of conflict or resistance over the development of PV technologies in particular places?
5. What are implications for the future expansion and innovation of PV technologies in Europe?

After a period of research training and the development of the conceptual framework for the project, the methodology involved will consist of the following stages to address these research questions:

- A desk study of urban PV initiatives across Europe, including EU and national level programmes and schemes promoted by networks of cities (e.g. energie-cites, European Solar Cities initiative) and individual municipalities (R1 and R2).
- The selection of up to four case-studies in up to three different European countries for in-depth analysis and comparison (R3, R4 and R5).
- Case-study research in the selected cities, comprising of the analysis of policy documents and semi-structured interviews with policy-makers, practioners, private and community sector actors involved in PV projects, and other representatives from the building development, insurance and selling industries. Selected interviews with key national and European level actors as appropriate (R3, R4 and R5).

An outline timetable is attached. Note that this will be subject to change as the project progresses but provides an indication of the relative amounts of time allocated to each task.

Research findings and output

The research findings will contribute to our knowledge of the factors which are facilitating and preventing the embedding of PV technologies in European cities, and the lessons which can be learnt for the development of future PV technologies and energy policies. It will also contribute to current academic debates about how we might develop multidisciplinary ways of understanding the social and technical relations which shape the trajectories of (energy) technologies

The output from the research project will consist of a PhD thesis, two conference papers presented at UK and international conferences, and a paper for a peer reviewed journal. In addition, reports on each case-study and interim reports will be made available to Sanyo throughout the research project, and a final report and presentation will be provided.

Research supervision and collaboration

The research project will be supervised by Dr. Harriet Bulkeley and Dr. Karen Bickerstaff in the Department of Geography, Durham University. Prof. Ken Durose will act as an Academic Advisor, and the student will be affiliated to the Durham Centre for Renewable Energy, enabling them to gain expertise from the other researchers working with DCRE.

The Department of Geography has a rigorous process of student supervision in place. Students and supervisors meet at least 12 times a year, and are required to complete forms recording their meetings and action plans. Students undertake generic research training in Geographical theory and methods during their first year, and are required to submit an initial report on conceptual frameworks, a First Year Report on the structure and progress of their project, as well as second and third year progress reports. Together with the supervisory process, this ensures that students are carefully monitored and assisted in the completion of their thesis.

The partnership with Sanyo will be critical to the success of this project. We envisage that quarterly meetings will be held in Durham with a representative of Sanyo, the student and the project supervisors. The student will also spend time with Sanyo to learn about and study the technical and social issues of PV manufacture and emerging innovations, and the wider business environment of PV technologies in Europe. One visit will be made to Hungary, and the rest to the UK offices of Sanyo Europe. Interim reports will be made available to Sanyo and a final report and presentation will also be given. A separate IPR agreement will be reached.

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