Reconfiguring the city in the global South: rationalities, techniques and subjectivities in the local governance of energy

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Abstract

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Debates around climate change and resource security are reshaping the way cities conceive and develop their infrastructures. Electricity systems play a key role in this transformation, as cities across the world set out to implement local energy strategies via decentralised and low carbon energy systems. Such transformation is of particular relevance for cities in the global South, where rapid economic growth and an increase in energy consumption coexist with acute social needs and unmet infrastructure provision. Through a comparative study of two cities (Thane, in the Mumbai Metropolitan Region, India, and São Paulo, in Brazil) this thesis evaluates the way in which public and private stakeholders are implementing a new form of local energy generation through the use of domestic solar hot water (SHW) systems as a mechanism for reducing electricity consumption. By focusing on the governing mechanisms involved in scaling-up solar technologies and the ways by which these are mobilised to serve contrasting interests in the city, the thesis examines the emerging local governance of energy in the global South.

The thesis uses Foucault's analytics of governmentality as a conceptual tool aimed at unpacking the different ways by which energy in the city, in its material and socio-political formations, is thought of, mobilised, and transformed. Through a combination of interviews, site visits, and ethnographic techniques, it examines how this transformation in urban infrastructures is changing the manner in which energy is governed, the spatial and socio-political implications of this transformation, and the way in which the material dimensions of SHW systems influence the transformation process. The thesis discusses the governmental rationales involved in the making of a local governance of energy, the key governmental techniques involved in operationalizing a solar energy regime, and the multiple ways in which energy subjects are imagined within this process.

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Summary Contents

Table of Contents

Index of tables and figures

Chapter 5

Chapter 6

Chapter 7

List of Abbreviations

ABINEE	Brazilian Electrical and Electronics Industry Association
ABRAVA	Brazilian Association of Refrigeration, Air Conditioning, Ventilation and Heating (see DASOL)
ANEEL	National Agency for Electricity, Brazil
ANT	Actor-Network Theory
BNDES	Brazilian Development Bank
BRICS	Brazil, Russia, India, China and South Africa
CDHU	São Paulo's Housing and Urban Development Company
CEA	Central Electricity Authority, India
CESP	Energy Company of São Paulo (state level)
CCP	Climate Change Policy, São Paulo (city level)
CCAP	Climate Change Action Plan, São Paulo (city level)
CNG	Compressed natural gas
DASOL	Brazilian Association of Manufacturers of Solar Hot Water Systems
DIY SHW	Do-it-yourself solar hot water system
ESCO	Energy services company
GHG	Greenhouse gas emissions
ICLEI	ICLEI – Local Governments for Sustainability
INMETRO	National Institute of Metrology, Standardization and Industrial Quality, Brazil
JNNSM	Jawaharlal Nehru National Solar Mission, India
LPG	Liquefied Petroleum Gas
MEM	Ministry of Energy and Mines, Brazil
MSEB	Maharashtra State Electricity Board, India
MNRE	Ministry of New and Renewable Energy
NGO	Non governmental organization
NMEEE	National Mission on Enhanced Energy Efficiency, India
MJ	Megajoules
MtCO2e	Million tonnes CO2 equivalent
MW / MWh	Megawatt / Megawatt hour
NAPCC	National Action Plan for Climate Change, India
NEEP	National Energy Efficiency Plan, Brazil
PROCEL	National Electricity Conservation Programme, Brazil
PROINFA	National Programme of Incentives for Alternative Electricity Sources, Brazil
QUALISOL	Brazilian Supplier Qualification Programme for Solar Heating Systems
REEERC	Renewable Energy and Energy Efficiency Resource Centre
SEB	State Electricity Board, India
SHW	Solar hot water
SPMR	São Paulo Metropolitan Region
TMC	Thane Municipal Corporation

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Chapter 1

Introduction

Debates around climate change, resource constraints and the problematisation of energy demand are reshaping the way that cities conceive and develop their infrastructures. Electricity systems play a key role in this transformation. Cities all over the world have started experimenting with local energy strategies, combining energy efficiency, decentralised systems and low carbon technologies. Such transformation is of particular relevance for cities of the global South, where rapid economic growth and an increase in energy consumption coexist with acute social needs, fragmented infrastructure networks and unmet infrastructure provision. This thesis examines the emergence of a local governance of energy in Thane (India) and São Paulo (Brazil). It focuses on the governmental rationalities, governmental techniques and subjectivities involved in the development of a solar energy regime based around domestic solar hot water (SHW), and the ways by which the resulting energy form is mobilised to serve contrasting interests in the city.

1.1 Contextualising the research and establishing its aims

Urban infrastructure networks, such as electricity, water, sewerage, transport, waste and telecommunication systems, are considered to be the key physical and technological assets of cities. Infrastructures, as both the means and the object of governing, should not be understood exclusively as a collection of material components – the pipes, cables, buildings, and flows of resources – but as socio-technical assemblages that include state and non-state organisations as well as human and non-human agents (Graham and Marvin, 2001). Infrastructure networks are not free from political, cultural and symbolic representations and implications (Nye, 1994; McFarlane and Rutherford, 2008). They structure and delineate the experience of modern urban life and, in "subtle and powerful ways… define, shape and structure the very nature of cities" (Graham and Marvin, 2001: 30).

In recent years infrastructure networks have come to the forefront of urban agendas in a number of ways. Urban governance is increasingly shaped by calls for the transformation of infrastructure networks in response to issues of climate change, resource constraints and other challenges perceived to affect the economic and ecological reproduction of the city (Hodson and Marvin 2009b; Bulkeley, 2010). As these challenges focus cities' attention onto electricity regimes, electricity infrastructures emerge both as a challenge and an opportunity for the sustainability of the city (Bulkeley, 2013). Yet, as urban infrastructures are transformed, a new configuration of power relations comes to being (Hodson and Marvin, 2010; Monstadt, 2007). This results in new modes of governing both the infrastructures that provide critical services and the very population that benefits from them, opening opportunities for the emergence of new socio-political orders in the city. In the city of the global South, historically characterised by fragmented urban fabrics (McFarlane, 2008; Gandy, 2006; Kooy and Bakker, 2008) and more recently by competing agendas around issues of poverty, infrastructure provision, sustainability and climate change (Bulkeley et al., 2009; Lasco et al 2007, cited in Bulkeley, 2010; Romero Lankao, 2007b), the arrival of new energy configurations is inevitably entangled with broader urban agendas that mobilise the city's resources towards the fulfilment of multiple and often contrasting aims. Yet, the specific ways by which power operates in this transformation, the mechanisms through which the transformation takes place, and its contingent and often contradictory nature, deserve further examination.

To achieve this, this thesis uses Foucault's analytics of governmentality (2009) as an analytical tool aimed at unpacking the different ways by which energy in the city, in its material and socio-political formations, is thought of, mobilised, and transformed. The thesis draws on interpretations of governmentality developed by Dean (2009), Legg (2007b), and Li (2007a; 2007b), and uses the concepts of governmental rationalities, governmental techniques and subjectivities to conceptualise, respectively, the problematisation of energy, the mechanisms used to govern energy in the city, and the process of imagining subjects and identities as part of the governing efforts. Through a comparative analysis drawing on case studies on the implementation of SHW from Thane, in the Mumbai Metropolitan Region (India), and the São Paulo Metropolitan Region (Brazil), this research is founded on the following broad questions:

- How is the on-going urban energy transformation changing the manner in which energy, particularly electricity, is governed?
- How and with what consequences is this process occurring in cities in middle income nations?
- What are the spatial and socio-political implications of this transformation?
- What is the specificity of the materiality of solar technologies in this process?

1.2 Approach

In 1979 Foucault outlined the notion of governmentality (2009) as an analytical tool for understanding power dynamics within a mode of governing "distinguished by trying to work through the freedom or capacities of the governed" (Dean, 2010: 23). Foucault's intent was to place the emphasis on the specific mechanisms by which governing occurs: the *hows* of governing. Here, in the context of 'conducting the conduct' of the self and of others, *governing* is seen as the art of achieving the "right disposition of things" (Foucault, 2009: 98-101). Since then, the notion of governmentality has been elaborated by a variety of scholars, resulting in complementary emphasis and different ways of understanding it.[1] This thesis draws on three particular perspectives: Dean's (2010) and Legg's (2007b; 2011) emphasis on regimes of government and their constitution through governmental rationalities, governmental techniques and subjectivities; and LI's (2007a; 2007b) acknowledgement of the 'will to improve' as the – never fully achieved – desire to effect positive change in society, and of assemblages as the fragmented and contingent sites for agency.

Governing, thus, is different to *government*, where the focus is on the institutions and actions of the state. Governing is seen as the purposive attempt to steer society, implicating "a focus on how collective action is organised and conducted" (Bulkeley et al., 2007: 2734). This attempt to govern does not sit exclusively within the domains of the state. On the contrary, it is done by a variety of stakeholders, from national governments and municipalities to NGOs and business associations, amongst others (Adger and Jordan, 2009). In this context, references to the changing governance of energy point to an empirical phenomenon in the process of ''authoritatively allocating resources and exercising control and

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[1] There is not one single unequivocal 'governmentality' but a multiplicity of them. Drawing on Foucault, geographers, anthropologists and sociologists alike have actively and in different ways engaged with the concept. In developing an analytics of government, amongst others, Rose and Dean emphasize the role of freedom and the agency of the state (Rose, 1999; Miller and Rose, 2008; Dean, 2010), Li the workings of power through assemblages (2007a; 2007b), Legg the role of resistance as a pre-condition to power (2009; 2011) and McKee the paradoxical coexistence of subject formation and the devolution of power (2009; 2011). The debate around its interpretation and development is not closed, with scholars criticising the development of 'decidedly un-Foucauldian' governmentalities (McKee, 2009; Rutherford, 2007) and arguing in favour of embracing Foucault's original critical spirit (Gibson-Graham, 2003).

co-ordination'' (Rhodes, 1996: 653).[2] It is a process that shows changes in the form and function of the state, particularly "its diminishing size and increased tendency to deploy less coercive policy instruments", alongside the appearance of new forms of steering conduct (Adger and Jordan, 2009: 11).

An analytics of governmentality provide an understanding of the ways by which the transformation of energy regimes, and the emergence of a local governance of energy, involve new ways of governing infrastructures and population through them. It also enables an understanding of how this transformation process re-defines political and spatial relationships between the agents involved in energy provision, including the scalar categories traditionally used to think about resource provision and consumption such as the nation, the city and the dwelling. In this thesis, as a critical analysis of the 'will to improve' energy infrastructures in the city, the use of an analytics of governmentality implies, first, an evaluation of the rationalities that lead to the emergence of a solar energy regime and, through that, a local governance of energy. This means reviewing the ways in which energy is problematised in the city, and the manner by which specific technological solutions, such as SHW, emerge as the preferred answer. Second, it also means unpacking the specific governmental techniques that make up this local energy regime, detailing the ways in which new socio-technical configurations align for the purpose of generating energy locally. Third, it requires evaluating the ways in which governing energy infrastructures and their users, occurs by involving subjects and their identities. Governing energy locally "operates by educating desires and configuring habits, aspirations and beliefs" (Li, 2007b: 5). This occurs through processes of subjectification, such as the generation of energy awareness and the development of associations between

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[2] The notion of governance in this thesis is not used as a theoretical tool addressing issues of control, co-ordination and accountability (Flinders, 2002), neither it is used as a normative prescription determining the preferred way of going about the management of the public – such as the 'good governance' approach used by the World Bank (Kaufmann et al., 2002; Kaufmann et al., 1999).

normative notions of citizenship and particular energy behaviours. Finally, in analysing new configurations of energy infrastructures in the city, the way in which issues of power, domination, and stability over time, are linked to the material dimensions of the city is of particular importance. Materiality enacts power and underpins the regime, both framing the possibilities for realisation of the governing efforts and establishing the means for resistance and reinterpretation.

1.3 The new geographies of energy

From coal and steam power to gas lines and electricity networks, energy has been indispensable for the birth of the contemporary networked city (Nye, 1999: 94-99). Cities are concentrated nodes of energy consumption, and their industrial, domestic, leisure and security demands have been the drivers behind the most significant advancements in energy systems in modern times. Electricity makes the city possible by connecting and circulating resources across different scales and sites, and allowing the functioning of other networked infrastructures that enable urban life (Nye, 2010: 26). It traverses territorial, social and political boundaries, underpinning urban growth and economic wellbeing at both local and regional scales (Monstadt, 2007). In this way, electricity is geographical by nature.

An important concern of this thesis is an analysis of how this reconfiguration of energy systems, which sees the city both as an energy problem and as a privileged space of intervention towards the development of solutions, depends upon a series of spatial reconfigurations. Recent trends in human geography inquire into the geographical implications of the transition of energy systems towards low carbon modes, pointing to the on-going "reconfiguration of current patterns and scales of economic and social activity" (Bridge et al., 2013: 331; see also Zimmerer, 2011). As research practice, the 'new geographies of energy' highlight "the different geographies and governance challenges associated with an energy future based upon… highly distributed forms of household micro-generation… [and] the way in which spatial processes shape energy systems and influence their capacity for transformation" (Bridge et al., 2013: 332). These geographical inquiries are in line with a resurgence of energy topics in the social sciences, where energy research is reconfigured as a social, rather than a scientific challenge, and its practice ventures beyond the "ready made but limited roles [of] addressing the so-called 'human dimensions' of energy efficiency" (Guy and Shove, 2000: 2; see also Rohracher, 2008; Strauss et al., 2013).

The experience of Thane and São Paulo demonstrates how, in putting in place a local governance of energy, energy is re-territorialised. Here a new set of assumptions around "the geographical scale at which energy systems should be governed" enters into action (Bridge et al., 2013: 331). This means that spatial meanings are re-codified, boundaries are redefined, and new circulations established. The energy problem is no longer a matter of national security, but is also concerned with different forms of security at local levels, from securing urban growth to domestic forms of life and affordable resource access for citizens (Buzar, 2007; Walker, 2008). The city and its rapid growth trends are often seen as a menace for the nation's ability to provide energy, becoming the new focus for governmental interventions around energy. In this context, local energy programs are promoted by national and local governments alike, and a new portfolio of decentralised and 'post-networked' technologies emerge (Coutard and Rutherford, 2011). SHW, as a new energy form, depends on the relocation of energy dynamics in the domain of water, or, to put it in another way, the extension of the city's energy infrastructure to include dwellings and their plumbing arrangements. It relies on a variety of local circulations, including plumbing knowledges and the techno-natural material circulation of solar energy through pipes and water. In this way, through SHW and the replacement of electricity originally destined for water heating for bathing and showering purposes, both city and dweller become energy producers, whilst urban energy infrastructures are no longer seen exclusively as the key networks for supply but also as sites for energy generation. In doing this, the local governance of energy redefines the meaning and boundaries of urban infrastructures.

Paraphrasing the approach set out by Guy and Shove when establishing a sociology of energy (2002: 8), this thesis explores how “methods and arguments drawn from [geography] might be applied and how they might fare alongside more conventional, more technological, representations of the energy problem”. In contrast to Guy and Shove, the emphasis is not on the ways of conducting energy research (e.g. the point of view of research managers and those promoting a scientific agenda), but on the practices associated with the on-the-ground implementation of a decentralised energy form. In doing this, the urban energy problem has been examined from the point of view of the national and local government organisations rolling out local energy strategies, the NGOs advocating for and participating in the deployment of renewable technologies, the manufacturers and business associations involved in developing solar business, and finally, the dealers and installers bringing these energy modes to the dwelling. An emphasis on the material dimensions of this energy agenda, by considering the active role of material supplies, pipes, water and other material agents (Bennett, 2010), enables points of connection with more technological approaches to energy. Yet, throughout the text the thesis suggests the need to tackle the low carbon energy transformation away from “one-dimensional techno-centric solutions” and towards a consideration of the “underlying geometries of power and social justice” involved (Bouzarovski–Buzar, 2009: 2).

1.3.1 Energy and development

Affordable access to electricity plays a key role in promoting social agendas and achieving urban justice (UNDP, 2009; UNDP, 2013). In 2012 the

United Nations launched its Sustainable Energy for All initiative. As part of it, the Global Action Agenda recognizes the central role that energy plays in the achievement of the Millennium Development Goals. It also commits the United Nations to take action towards three specific energy objectives for the year 2030: to ensure universal access to modern energy services, to double the global rate of improvement in energy efficiency, and to double the share of renewable energy in the global energy mix (United Nations, 2012).

Both acknowledging and problematising the interface between energy and development is part of the new geographies of energy that frame this thesis. On a global scale, as of 2010, 74.1% of the population had electricity access. There are significant differences in access depending on income level, as only 23% of the population in low-income countries had access, compared with 81.5% in middle income countries (World Bank, 2013c). There are still further differences in relation to rural and urban populations. As of 2009, only 68% of the world's rural population had electricity access compared to 93.7% in urban areas (IEA, 2011). However, this high rate of electricity access in urban areas occurs, for many of those living in the city of the South, in the form of irregular, patchy and informal connections. This thesis reveals how the energy and development debate goes beyond issues of access. It is a debate that spans across a multiplicity of other domains, such as energy affordability, reliability and universal service provision, and demands that questions are asked around the dominant development models that prescribe energy for what and energy for whom.

1.4 Contributions

The thesis makes four empirical contributions, discussed in greater detail in the conclusions (Chapter 8). First, the thesis uncovers the local distinctiveness of local energy regimes. The main purpose of the thesis is to compare the process of transforming urban energy infrastructures and adopting solar technologies as a local energy solution in Thane and São Paulo. In both cities, as well as in many other cities across the globe, this process is framed by shared governmental rationalities around resource constraints, climate change and energy demand. It would appear at first sight, given the global purchase of such rationalities, that the process of transforming energy infrastructures plays out in similar ways across different locations. However, the thesis reveals the extent to which these seemingly consistent urban processes have very different local manifestations. Common ways of thinking about the urban energy problem are adapted and reinterpreted at local levels in significantly different ways.

A second contribution revolves around the extent to which the resulting solar energy regime is underpinned by an urban ethos of energy. Such an ethos, adopted through the local problematisation of energy, plays a constitutive role in establishing local differentiation. It determines the manner in which local energy regimes reflect local concerns; it also defines what the new energy form (solar, in this case) is for, and who has access to it. Whilst both cities are actively engaged in developing climate change responses, considering issues of resource constraints as a key driver, and problematising issues of energy demand, the solar energy regimes that emerge are different, precisely because they are underpinned by a different ethos. In the case of Thane, an ethos around urban growth determines that SHW technologies are to play a role in support of the growth priorities. It also operates in the space of the middle upper and upper sectors of society, the social forces driving such growth. In the case of São Paulo, an ethos informed by broader logics and which embraces social agendas results in a solar energy regime that spreads the benefits of solar energy across broader segments of the population, with a strong emphasis on low-income groups.

A third contribution is the result of the attention given to spatial categories in the analysis of the solar energy regime. Through this, the thesis explicitly draws out the re-territorialisation of energy processes occurring through the establishment of a solar energy regime. This is illustrated in a multiplicity of ways; through an analysis of how SHW redefines boundaries between users and infrastructure and between sites of energy generation and consumption; through an examination of the new forms of circulation required in the local generation of energy, particularly the circulation of energy through water and the circulation of knowledge around plumbing; and through an examination of the local and dispersed relationships and sites involved in the implementation of SHW, including the relationships between government offices and NGOs promoting the use of solar technologies and the manufactures, dealers and installers involved in delivering the technology on the ground. This points to the fourth empirical contribution: the thesis shows how the incorporation of diversity and multiplicity is what enables the local energy regime to operate. Diversity and multiplicity take different forms in the solar energy regime. Multiple scales beyond the city are involved in its configuration, from global and national scales to micro-local scales such as the dwelling. There is also a multiplicity of agents operating in a dispersed manner, both within and outside the city boundaries. Similarly, the solar energy regime is operationalised through a variety of different governmental techniques (from calculation techniques to standards). Finally, a multiplicity of modes of power is at play, including governmental powers that operate though the freedom of those who are governed (e.g. via voluntary standards) as well as sovereign powers that operate through coercion (e.g via municipal solar laws).

Methodologically the thesis is based on a comparative study of two cities. This comparative study has been informed by an ethnographic sensibility, and the fieldwork was approached through the lens and data collection strategies provided by an ethnography of infrastructure (Leigh-Star, 1999; Leigh-Star, 2002; Leigh-Star and Bowker, 2006; Hess, 2001). The use of ethnographic sensibilities within comparative urban studies, and the reflection generated around this research practice, can also be considered as a contribution of the thesis, albeit from a methodological perspective. Yet, attempting to carry out an ethnography (which requires dwelling) in the context of urban comparison (which requires traveling and is characterised by a multi-sited nature) was a challenging experience. In the context of the limited research time afforded by a PhD, this combination was not exempt from the anxieties referred by Marcus as the concern around the 'attenuation of the power of the fieldwork' (1995). The result has been termed 'a traveling ethnography of urban technology'. Rather than an ethnography in its traditional sense, a traveling ethnography of the urban is non-linear, embraces contingency and combines a multiplicity of methods (e.g. participatory observation and interviews) at different times and in different intensities. As a research contribution, the use of ethnographic sensibilities in urban comparative studies is not intended to operate as a consolidated proposal or provide a clearly shaped methodology. In contrast, the contribution lies in the experimentation with such methodology, with varying degrees of failure, and on the reflection around it, opening the problem to questioning and highlighting a challenge for the future.

1.5 Thesis structure

The thesis is structured in eight chapters, including this introduction. It starts by providing a general context to the research (Chapter 2), focusing on the history of electricity regimes in Brazil and India and discussing contemporary challenges and dynamics. This is followed by a presentation of Foucault's (2009) analytics of governmentality as the thesis' conceptual framework (Chapter 3) and a discussion of the methodological approach (Chapter 4). The empirical analysis starts by discussing the governmental rationalities that enable energy to emerge as an urban problem and solar technologies as a solution (Chapter 5). This is followed by an analysis of key governmental techniques involved in the operation of the solar energy regime (Chapter 6). The final empirical chapter discusses the multiple ways in which the energy subject is imagined within the regime, where energy subjects appear as citizens, consumers and producers (Chapter 7). This chapter also opens a discussion around how solar energy is imagined in relation to the subject, linking this to questions around what is the purpose of such new energy modes and who is included and excluded from the emerging solar energy regime. The thesis finishes with a set of conclusions (Chapter 8) elaborating on the research contributions, providing a number of policy recommendations and pointing to possible future research agendas.

1.5.1 Context: historical and contemporary ways of thinking about electricity

By way of context, the thesis starts by discussing the centralised mode of thinking about electricity present in Brazil and India throughout the second part of the 20th century. **Chapter 2** begins with an historical account of the process of centralisation and nationalisation of electricity infrastructures started in the 1950s. Here energy infrastructures are revealed as key tools in the hands of the central state playing a role in governing population and advancing key national agendas, particularly development, industrialisation and national security. In India, throughout the 1950s, 60s and 70s, large dams for the purpose of irrigation and electrification are symbolically constituted by the post-independence government as the representation of modern India. Yet, the power they commanded (in the form of electricity) is co-opted by regional elites and bureaucrats, who use electricity as the means to maintain political power. In Brazil the military government of the 1960s and 70s developed a highly centralised electricity regime based on hydropower. Electricity operates as a key input for the country's much needed industrialisation and also a means of achieving national security via territorial expansion and energy independence. The resulting regime focuses on supply and fosters energy intensive practices. It also embeds a spatial separation between nodes of electricity generation, management and consumption, dislocating local perspectives from the decision making process.

The 1990s and 2000s bring a reversal in nationalisation trends worldwide. In Brazil, the deregulation and privatisation process starts in the mid-1990s, framed by a national economic crisis. In India it starts in the early 2000s and to this date has not been fully implemented. Alongside deregulation, a new set of challenges impose constrains on the electricity system, primarily in the form of demand growth and limited supply capacity leading to nationwide blackouts (Brazil) and questions over the ability of the country to deliver the required power to maintain projected economic growth levels (India). Energy efficiency emerges as a key strategy for energy management, whilst a new set of agendas around climate change lead to a consideration of alternative energy strategies based on renewables. In this context, the city emerges as an important actor in the development of energy strategies.

1.5.2 Conceptual framework and methodology

Urban geography has had a long engagement with networked infrastructures, leading to a multiplicity of conceptual entry points for an analysis of urban energy infrastructures. **Chapter 3** reviews this literature, and lays down the thesis' conceptual framework. It asks three questions. First, how do energy infrastructures configure the urban? Second, what agencies are enabled – or disabled – by energy infrastructures, particularly in the context of urban sustainability debates? Third, how do certain forms of user interface foster specific understandings of the city and its infrastructure? In answering these questions, the literature review illustrates the political and symbolic nature of urban infrastructures (Graham and Marvin, 2001; McFarlane and Rutherford, 2008; Kooy and Bakker, 2008); the prominent role their reconfiguration plays in the development of responses to climate change and sustainability discourses (Hodson and Marvin, 2009; Bulkeley et al., 2011; Bulkeley and Castán-Broto, 2013); and the role that municipal and other urban stakeholders play in this process (Guy and Marvin, 2001; Hodson and Marvin, 2010). The review also highlights the primary role of subjectivities in the make-up of infrastructures and how different understandings of the user result in different understandings of the infrastructure itself (van Vliet et al., 2005; van Vliet, 2004). A different type of user, one that not only consumes energy but also generates it, emerges from a post-networked mode of urbanism which is based on decentralised and small-scale technologies (Coutard and Rutherford, 2011).

The thesis argues that the literature reviewed provides limited detail about the actual mechanisms at play in the transformation of energy infrastructures in the city, leading to a restricted understanding of the interface between the specific social, material and political mechanisms in operation. This highlights the need to pay greater attention to the messiness, multiple contradictions and contingent nature of the process of transforming energy infrastructures in the city, and the need to consider how the multiple agencies and identities involved (and imagined) shape the outcomes. To overcome these limitations, the thesis proposes the use of an analytics of governmentality (see Section 1.2 above). The resulting approach combines three modes of analysis: an evaluation of the governmental rationalities involved as ways of problematising energy in the city; an understanding of the governmental technologies involved in operationalising the regime; and a consideration of the imagined subjectivities and identities required for the process (Foucault, 2009; Dean, 2010; Legg, 2007; Li, 2007a; Li, 2007b). The proposed governmentality approach is attentive to the ways by which processes of re-territorialisation (Crampton and Elden, 2007) are entangled with making energy locally. Similarly, governmentality offers productive entry points for an understanding of the material dimensions involved in the activity of governing, specifically the "government through and by technology" (Otter, 2007: 578, original emphasis; see also Joyce, 2003).

The thesis' methodological approach, discussed in **Chapter 4**, maintains this emphasis on the material dimensions of the emerging local governance of energy. It is based on a 'traveling ethnography of urban technologies': an ethnography of infrastructure that follows the life of SHW in the city (Latour, 2005;

Leigh-Star, 1999). SHW systems are examined in their different incarnations, from the moment they are imagined as the bearers of urban energy solutions to the moment they are installed on the roofs of houses and towers. Taking cue from Marcus' multi-sited ethnographic practice (1995) and Clifford's traveling ethnographies (1997), the methodological approach acknowledges the itinerant nature of urban technology, from government offices to the nodes of energy advocacy and from factory to dwelling.

Yet this itinerant nature characterises the research object as much as the research itself, as the thesis sets out to compare how two cities locally experience an allegedly common global process of urban transformation. This form of comparative urbanism draws on similarity as much as it does on difference (Robinson, 2006; McFarlane and Robinson, 2012). Thane and São Paulo stand as comparable given their location in two BRICS nations. In a post-Kyoto world, both Brazil and India are facing pressures to adhere to international GHG emission reduction targets. Both São Paulo and the Mumbai Metropolitan Region are examples of the mega metropolises of the global South, characterised by rapidly changing consumption patterns and growing energy consumption. Both São Paulo and Thane are actively involved in shaping their own energy futures by implementing low carbon infrastructures. Just as important, both cities face similar challenges in terms of social justice and urban equity. Nevertheless, they are located in markedly different countries and enjoy significantly different social and political histories. They differ in extension, population size, administrative structure and urban configuration. Their differences stand both as an opportunity and a challenge for the generation of urban knowledge about the ways in which cities across the world are responding to the common challenges of climate change and resource constraints.

1.5.3 Empirical analysis: Rationalities, techniques and subjectivities

The thesis' empirical analysis is developed in three chapters, each dedicated to one of the key modes of analysis of the conceptual framework proposed in the previous section: the governmental rationalities involved in problematizing energy locally (Chapter 5), the governmental techniques involved in operationalizing the solar energy regime (Chapter 6), and finally, the processes of imagining subjects leading to a formation of energy identities (Chapter 7).

Chapter 5 examines how energy becomes an urban problem, and how solar technologies – particularly SHW systems – emerge as a preferred solution. In São Paulo and Thane, energy emerges in the city framed by three different rationalities. First, issues of resource constraints and the localisation of energy security, represented by the decision of India's Ministry of New and Renewable Energy (MNRE) to establish a Solar Cities Programme in response to the country's looming energy crisis. This occurs as demand substantially exceeds supply capacity, and the MNRE seeks ways to respond to the growing energy needs of an urbanised nation. In Thane, one of the first Indian cities to join the Solar Cities Programme, such energy constraints led to experimentation with alternative energy sources. Second, the problematisation of energy demand, exemplified by the challenges experienced by Brazil's electricity system as a result of the daily use of electric showers, and the steep peak demand curve that this generates. Third, climate change narratives also play a role in the emergence of energy as a local problem. Both Thane and São Paulo are actively involved in efforts towards GHG reduction, through involvement with international organisations and transnational networks working on the topic. Such engagement with climate change has led both cities to monitor their energy consumption and promote a low carbon urban agenda via renewable energy technologies.

In this context, SHW emerges as a viable solution for the (now urbanised) energy problem. Both cities receive high solar radiation and have seasonal weather patterns that allow for the use of SHW as an electricity replacement, displacing electric modes of water heating. However, the real power of solar technologies lies in their ability to materially reconfigure the energy infrastructures of the city, by generating energy out of water circulations. In São Paulo the resulting energy regime is aligned with the social agendas of the city and mobilised via social housing. In Thane solar technologies gain prominence thanks to a different ability: the symbolic power of solar imagery and its ability to fuel urban growth. In the midst of the rapid urban growth characteristic of the Mumbai Metropolitan Region, the seductive appeal of solar technologies and their visibility as a symbol of progress and eco-modernity are mobilised to secure the future of the city.

The mobilisation of solar technologies is to be achieved via a set of techniques, which play an active role in the local generation of energy. **Chapter 6** discusses the governmental techniques that make up the solar energy regime, drawing not only on the institutional agencies of local government, but also on the role of the manufacturers, dealers and installers of SHW systems. The chapter illustrates the contingent nature of the regime: its operation as a dispersed and fragile arrangement composed of a multiplicity of scattered agencies that, together, generate a new socio-spatial configuration of urban infrastructure. Governing solar energy in this context involves techniques for calculating energy, thus making it locally visible (and in this way, making it into an object that requires governing), constructing the field of intervention (Dean, 2010), and enabling present and future action. For this, in the case of Thane, the municipality relies on energy baselines, targets and masterplans. Governing solar energy also involves standardising energy, as a way of governing the required knowledge and material relationships that relocate energy generation within the domains of domestic plumbing. In São Paulo this is reflected in a variety of standards associated with material quality and professional practice in the process of manufacturing and installing SHW systems, primarily under the leadership of the private sector. Here, local energy is the result of forging new alignments between energy and water infrastructures.

In establishing a local governance of energy via SHW, governmental and coercive techniques operate in tandem (Foucault, 2009; Dean, 2010). Both Thane and São Paulo enacted local laws mandating the use of SHW in new construction. The fate of these solar laws illustrates the extent to which governing energy locally is prone to failure and break down, particularly in Thane, where housing developers resist the implementation of a functional SHW strategy by commissioning low quality or undersized systems. This allows them to comply with the law whilst minimising the financial burden associated with this new energy mode. In this way, in Thane, the possible failure of the solar energy regime risks the reputation of solar technologies. In contrast, in São Paulo an emphasis on standards has avoided the emergence of this scenario. The chapter illustrates the limitations of the coercive power of the law, and the role of governmental techniques in enabling agency.

The thesis' final empirical chapter (**Chapter 7**) is dedicated to an analysis of the ways in which the solar subject is imagined within the solar energy regime. Governing energy locally relies on the reconfiguration of the identities of energy consumers, with municipalities claiming to be in a privileged position for this. A geography of power, based on proximity (to the user) and trust (Allen, 2011), explains such sentiment. The success of SHW systems involves the constitution of a new energy subject: one who is aware of the environmental benefits provided by SHW, and who is willing to adopt such an energy form, not only as a matter of choice but also, as a matter of duty. Shaping an energy citizenship operates as a mechanism for conducting energy conducts, and environmental and national identities collude in this process. In Thane, for example, engaging the citizen in solar energy initiatives is done through renewable energy resource centres aimed at energy awareness, and forums designed to increase public participation in the development of local energy programs. Other examples point to a different set of imagined energy identities in the making of the local governance of energy: those of consumers and producers. São Paulo's low-cost DIY SHW systems illustrate how the use of solar technologies reconfigures the user's role in relation to the infrastructure, where the user is seen as an energy producer in charge of manufacturing and maintaining his own infrastructure. Thane's emerging debate around the legitimate and appropriate uses of hot water (heated with SHW systems) illustrates how the user of SHW is seen as a consumer of both water and energy in need of regulation.

Engaging with the subjectivities involved in the local governance of energy leads to a final discussion using a different entry point to local energy, signalling paths for further research after the completion of the PhD. Here, instead of asking 'how is the subject imagined and configured in the solar energy regime?' the relevant question is 'how is solar energy imagined in relation to the subject?' This means examining who is included and excluded from the regime, who benefits, and what is the purpose of this new energy form? Delving into these questions identifies a sharp contrast between Thane and São Paulo. In Thane, solar energy is imagined as a 'premium product', operating primarily in the middle class and elite neighbourhoods of the city. In line with the city's focus on growth, SHW systems serve the needs of the growth agenda and of those for whom this growth is directed. In São Paulo, SHW is mobilised in the context of social agendas around social housing provision. Energy and sustainability discourses are reframed within the context of 'housing with dignity' debates, so that solar energy becomes a means for living lives of dignity.

Chapter 2

Brazil and India in context: ways of thinking about electricity

2.1 Introduction

This This chapter focuses on the multiple ways in which electricity has been thought about and acted upon in both countries, providing an historical and contemporary context to the electricity regimes of Brazil and India. It covers three historical periods: a) the process of centralisation and nationalisation of energy (electricity) infrastructures characteristic of the mid-20th century; b) the contemporary make up of electricity infrastructures, including an account of capacities and challenges, alongside an overview of the deregulation process of the 1990s; and c) the way in which climate change and renewable generation further problematise electricity regimes, particularly at the turn of the century, including a discussion around the interface between cities and climate change and the ways in which this plays out in Thane and São Paulo.

The three topics examined here are relevant to the transformation of urban infrastructures analysed in this thesis, as they inform historic and contemporary rationalities guiding the broad efforts associated with the governing of, and through, electricity infrastructures and the role of the city in this process. They also show that infrastructure transformation is not a new process but an on-going dynamic entangled with the continuous efforts to govern population (Chapter 3). This transformation develops gradually, punctuated by specific moments of crisis and re-conceptualisation. It is precisely such crises, and the problematisation that enfolds, that informs the rise of new rationalities around electricity (Chapter 5).

The first part of the Chapter draws inspiration from scholarly accounts of the social and political history of electric power (Hughes, 1983; Nye, 1999). However, it also points to the absence of comprehensive works about the history of electricity in the global South. From public lighting to blackouts and urban consumption, the history of electricity in the Western world has been often portrayed as an urban history (Nye, 1999; Cowan, 1983; Jonnes, 2004; Nye, 2010; Hughes, 1983). This is not necessarily the case in India and Brazil, where electricity has been more entangled with national development than with the specific history of the urban. The resulting electricity regime placed primary emphasis on an ever-growing attempt to secure supply through capacity increases, via large-scale technical interventions (see Evans et al., 1999). This centralised regime created conditions for energy-intensive modes of development, prone to crises through its disregard of the forms and sites of demand as much as a lack of attention to the social and political tensions present at local and regional levels.

2.2 Ideological grids: the central state and the making of electricity regimes in Brazil and India

The electrification of the world in the late 19th century began in cities, as Tesla, Westinghouse and Edison competed for municipal contracts for the provision of public lighting (Nye, 1999: 166). This race was won by Westinghouse, whose 'alternating current' technologies opened up the possibility for electricity to be generated away from the sites of consumption (Jonnes, 2004). This paved the way for regional and national sites of control to take precedence over municipalities in the development and management of energy strategies. Since the 1930s, in line with technological trends that started in the 'Fordist' era and as part of the implementation of Keynesian economic models, energy infrastructures were nationalised around the world (Graham and Marvin, 1995; Graham and Marvin, 2001), including in Brazil and India. Electricity ceased to be planned and managed within the domain of municipal governments, dislocating the city from the planning and management of energy resources and marking the start of the dominance of national and regional – over local – ways of thinking about electricity.

Over the second half of the 20th century electricity grids in Brazil and India played a key role in building the nation. Starting in the 1950s, after decades of private electric power provision, both India and Brazil nationalised and centralised electricity planning, management and control. The grid became not only the network through which electric – and other forms of – power are transmitted, but also, within the rise of large national infrastructures worldwide, a large-scale symbolic and material device aimed at governing population and controlling territory (Section 3.3.1). Both countries embraced a national development agenda through the extension of electricity infrastructures, yet they did this in different ways. In Brazil, in securing the means for industrialisation, electricity became a form of infrastructure through which the military regime established different forms of national security. In India, through rural electrification aimed at agricultural development, the electricity regime became a contested space in the struggle between central government and the regions for resource control. In the words of a renewable energy activist interviewed in São Paulo, they were not just energy infrastructures but 'ideological grids' (Interview P31).

2.2.1 National security through electric power: the making of Brazil's hydroelectricity system

For over 50 years Brazil has followed a water-based approach to electricity generation. Brazil's hydroelectricity strategy, devised in 1956 by president Kubitschek, experienced its most significant growth over the country's 20-year military regime (from 1964 to 1985). Inspired by the twin objectives of fostering industrialisation and responding to national security concerns (Hilton, 1987), the military regime consolidated the country's electricity regime through the centralisation of the infrastructures and resources required for development and modernisation. Arguably, this was an exercise in 'command and control' – a form of exercising authority and direction characteristic of military institutions where centralised decision-making and mission achievement are prioritised. Electricity and its infrastructure operated as a strategy for territorial control based on new forms of water circulation (Swyngedouw, 2007). This strategy had the triple effect of consolidating a centralised form of energy planning and management; putting in place a regime that functions through bypassing natural cycles, thus erasing local variability and dislocating the local from resource management; and establishing an energy template for the future based on high consumption and dependent on the continued enhancement of supply capacities.

Hydropower and the consolidation of a centralised approach to electricity

The Brazilian power industry dates back to the late 19th century, with the development of generation facilities and urban grids aimed at servicing a growing urban population. In the early 20th century, in the absence of a unified institutional framework at the national scale, local governments established their own rules and guaranteed private concessions for the exploration of electricity services. This process relied significantly on foreign technology and capital, particularly via Canadian and American companies (De Oliveira, 2003; Magalhães and Tomiyoshi, 2011; see also Centro da Memória da Eletricidade no Brasil, 2013). However, the arrival of a nationalist revolutionary government in the 1930s alongside the adoption of a development model based on industrial growth marked the beginning of a long-term transformation in the electricity sector. During the 1940s Brazil's growing electricity demand significantly outpaced the supply capacity of the existing foreign-held generation firms, resulting in widespread shortages

(Sternberg, 1985). By the 1950s, coinciding with the reinstatement of Brazilian democracy, a political consensus emerged around the strategic role played by the electricity sector in the nation's industrialisation and the need for state owned companies to lead the sector (De Oliveira, 2003).

From the 1950s to the 1980s, Brazil's electricity regime went through significant changes in ownership, management modes and dominant technologies, resulting in high levels of centralisation, achieved via two types of intervention. First, via the nationalisation of electricity infrastructure paired with an administrative centralisation, where the federal government increasingly played a greater role in devising and implementing energy strategies. Second, via a technical centralisation that responded to the nature of the specific strategy implemented – hydroelectricity – operating as a territorial strategy for managing resources at a national scale.

In 1964, at the time of the coup-d'état that overthrew the Labour government of president João Goulart, Brazil's main development challenge was the inadequacy of its infrastructure. The existing limitations in electricity provision were perceived as a bottleneck standing in the way of national development. Despite 20 years of GDP growth at an annual average of 6%, electricity shortages were commonplace and demand in large cities such as Rio de Janeiro and São Paulo could not be met in full (Skidmore, 1990; Sternberg, 1985). Shortly after coming to power, the military regime commissioned a series of interconnected hydroelectric power stations and dams aimed at increasing electricity capacity in the long-term (Eletrobrás, 2002). Amongst them, the Itaipu dam, located on the Paraná River between Brazil and Paraguay, became the largest hydro-electric dam in the world at the time, to be surpassed only four decades later by China's Three Gorges Dam. Between 1964 and 1985, electricity capacity grew to 36,000 MW, a 600% increase (Governo Federal do Brasil, 2010a).

The energy strategy laid out by the military regime drew on a nationalisation process that started in the 1950s. This nationalisation required the centralisation of energy planning, generation and transmission at the federal level, alongside a macro regional decentralisation process locating responsibilities for electricity distribution within companies owned by the state (provincial) level (De Oliveira, 2003). The establishment of Eletrobras, Brazil's national energy company, consolidated this transition from a largely disorganised, private and regionally based electricity regime to a centrally planned and state owned approach. Eletrobras introduced the notion of national energy planning, established long-term investment plans and adopted a strategic direction for the country's energy regime (Sternberg, 1985).

Through Eletrobras, the military regime oversaw the forceful integration of the planning and technical domains of the different state (provincial) level energy strategies and approaches (Magalhaes and Tomiyoshi, 2011). Control of the electricity regime was achieved via federal committees established for the operation of interconnected grids and the expansion of the country's generation and transmission capacities. "The share of Eletrobras controlled companies in the electricity sector investments rose from 32.6% in 1974 to 60.7% in 1983, [... with] the role of state's [provincial] companies in generation and transmission... gradually reducing" (De Oliveira, 2003: 5). Tensions between federal and state level energy companies over funding allocation, pricing models, tariff systems, strategic planning and growth plans were common throughout the 1970s and 1980s. Yet the federal government was always seen as favouring the views and needs of the centralised Eletrobras.

However, centralisation was not only the result of administrative procedures. The technological nature of the infrastructures put in place, and their use as a devices for territorial control, also played a role. From a technical perspective, the centralisation of Brazil's electricity infrastructure was aimed at capturing opportunities provided by economies of scale and achieving system integration leading to peak demand management at a national level (De Oliveira, 2003). It was also a key strategy for managing risk and transferring vital energy and water resources from one region to another (Silva, 1997). Hydropower requires central planning and regional interconnectivity to balance the risk created by unpredictable hydrological cycles. In contrast to energy strategies based on thermal power, where plants are staggered and respond to demand in a sequential way – with the cheapest to run coming on-line first – hydroelectric power provides a cheap and constant supply of electricity regardless of the demand. Thus, the operation of hydroelectric systems does not depend on running costs and fuel availability, but on water availability. Yet the latter is hard to predict given the uncertainty associated with meteorological conditions. Risk resulting from adverse hydrology is difficult to identify given its dependency on annual and multi-annual weather cycles (De Oliveira, 2003). To overcome this limitation, hydroelectricity favours centralised operational modes where water, now as a key resource for the national economy, is transferred in the form of electricity from basin to basin and region to region, depending on need.

Hydroelectric plants were planned for all regions in the country, facilitating a form of territorial control via large infrastructure projects. The highly centralised hydroelectricity approach of Brazil has been criticised for its dislocation with resource management dynamics at the local level. Resources are controlled by the needs of "large capital defined in terms of macro-regions and the whole of national territory" (Silva, 1997: 90). The resulting limits imposed on localised management foster depletion and degradation (Silva, 1997). The remote location of generation and the need and ability to move resources from one macro-region to another also has implications for the way in which electricity is conceived, promoting an emphasis on ensuring supply rather than fostering demand based management. The former was a common feature of electricity regimes across the globe until the 1970s, when, following the energy shocks of the oil crises, awareness on energy alternatives and the need to consider demand over supply became more common (Nye, 1999: 260).

Energy infrastructure as a means for national security

For the military, electricity was to play one other role besides furthering the country's industrialisation: it was an important tool for national security. Security here has two dimensions: internal security, to be achieved via territorial expansion through large infrastructure projects, and external security, to be achieved via energy independence. The construction of large dams and hydroelectric facilities provided the military regime with an opportunity to secure the territory, a vital requirement in a vastly unexplored and large country such as Brazil. Throughout the period of the military regime Brazil's geopolitical approach was based on a doctrine of internal expansion (do Couto Silva, 1967). At the time of the Cold War, and in the context of left-wing armed movements throughout all Latin America, national security was defined by the notion of 'the internal enemy'. General Golbery do Couto Silva, the architect of Brazil's National Security Doctrine, defined in 1967 Brazil's geopolitical imperative as the complete control of the national territory (Ludwig, 1986). Following these guidelines, territorial presence is to be achieved through large infrastructure facilities and their access roads, particularly via the development of hydroelectricity. Electricity serves not only as a tool for economic integration and large-scale resource management, but also as an explicit strategy for territorial occupation which, over time, would become a contested terrain through the opposition of local stakeholders, indigenous groups and environmental organisations (Cummings, 1990; Cummings, 1995).

Yet the military regime did not define national security strictly in relation to its national territory. Hydroelectric power allowed Brazil to reduce its dependency in thermal imported sources such as coal and oil. As a result of the oil crises of 1973 and 1979, and with a large-scale hydroelectric programme fully under development and a surplus of electricity in the market, a transition from oil-based energy to electricity was encouraged (Governo Federal do Brasil, 2010b). At the time of the second oil crisis Brazil was importing over 40% of its total energy resources, including 80% of its oil and derivatives. By 1990 these figures went down to approximately 25% and 43% respectively (Governo Federal do Brasil, 2007: 41). Through a combination of oil scarcity and a newly developed hydroelectric future, electricity became "the domestic alternative" (Sternberg, 1985: 36). National security was reframed in terms of independence from imported resources. Under difficult economic conditions, switching to electricity did not only mean national security but also a more favourable trade balance. This energy transition was encouraged via tax-concessions and preferential tariffs. The industrial sector was one of the first to convert from petroleum to electricity, with water pumping for irrigation and other rural uses following through (Sternberg, 1985). Cities and regions were also involved in endorsing the new electricity regime. In São Paulo, the state level Energy Company of São Paulo (CESP) launched in 1981 its Electricity for Energy Independence programme (*Electricidade para a Independencia Energetica*), laying out a 10-year transition plan from petroleum to electricity. São Paulo's public transport system became an example of such transition with the addition of electric trams, as, in the words of CESP's President, it was transformed in order to take advantage of the country's "surplus electricity" (Sternberg, 1985: 39). The highly energy intensive electric shower is another technology that finds a niche in this era of electricity abundance (Governo Federal do Brasil, 2010b), a shift that will be discussed in more detail in Chapter 5.

The long-term implications of Brazil's hydropower model

Hydroelectricity's rapid growth in Brazil was sustained throughout the second half of the 20th century. By 2009 Brazil had an installed hydroelectric capacity of 80,000 MW (Governo Federal do Brasil, 2010a). From 1972 onwards Brazil significantly reduced the amount of electricity generated via thermal plants, reaching its lowest point of 13% in the late 1990s. Whilst apparently securing an energy future, the emerging regime increases overall levels of risk, as the more flexible coal-based thermal power (which can easily be switched on and off) gives way to a weather-dependent hydropower (Leite, 2009). This transition to electricity results in three interrelated dynamics. From a purely material perspective Brazil acquires an electricity surplus, with the resulting effect of promoting high electricity use and energy intensive practices. From an energy management perspective, the transition generates an undue emphasis on supply-based models, fostering an arrangement where energy services are to be achieved mainly through growth in provision. Finally, from a spatial perspective, the resulting energy regime and the embedded separation between the nodes of generation, decision-making and consumption dislocates local practices from issues of resource use. The resulting regime, discussed in Section 2.3, would be called into question in the early 2000s, as an energy crisis in the form of national scale blackouts unfolds.

2.2.2 Temples of modernity: development and local resistance in India's electric makeup

Like Brazil, over the course of the second half of the 20th century India established a highly centralised electricity regime in response to the development and modernisation needs of the country. In post-independence India, the buildings of electric power became a symbol of modernity and an icon of central power. Jawaharlal Nehru, India's first Prime Minister and the architect of modern India, believed that the nation's entrance to modernity was to be achieved via technology and progress. Between 1950 and 1980 large dam projects aimed at developing the countryside via electricity generation and water irrigation came to symbolise India's modernisation, becoming the keystone for the country's radical transformation (Klingensmith, 2003). However, whist making significant steps in increasing generation and transmission capacity (Pachauri, 1982), India's centralised electricity strategy came close to collapse towards the end of the century as a result of the tensions and disagreements between central and local levels over political power and forms of control over resources (Morris, 1996).

The resulting form of electrification, and the central state's attempt to govern through infrastructure, reached its limits as regional stakeholders resisted the central power via the co-optation of the socio-technical networks devised to deliver an 'electric modernity'.

The nationalisation and partial-centralisation of India's nascent electricity sector

British colonial power was responsible for the introduction of electricity in India in the late 19th century. Private sector involvement in electricity generation and supply was formalised via the 1910 Electricity Act. Through hydroelectric facilities, familiar names such as the Tata Power Co played an important role in the early electrification of India (Madan et al., 2007). However, local governments were also involved in the establishment of electricity facilities. At the time of independence, four-fifths of the country's generation capacity was in private hands or local government ownership (Dubash and Rajan, 2001). At the time, electricity was used mainly for lighting purposes in major urban centres, alongside specific industrial uses in certain regions (e.g. gold mining in Karnataka and jute in West Bengal).

However, shortly after the country's independence, electricity became the exclusive domain of the state and its primary orientation was to change. Since the early days of India's independence in 1947, industrialisation, electrification and the large-scale management of water were seen as the primary needs of the young nation (Guha, 2007: 205). Electricity was an essential means for the industrialisation and modernisation of agriculture, and through this, essential for the promise of development. Large-scale electricity infrastructures, primarily through their material superstructures (dams and power plants), were to play a key role in the making of modern India. These 'temples of modernity', as Nehru himself would call them, were envisioned as key players in a highly centralised and developmentalist model that tried to monopolise the key inputs for modernity in the hands of the central state (Misra, 2007: 302; Wyatt, 2005; Guha, 2007: 212).

In 1948 the recently formed government set out to establish the new tools for the creation of an electricity regime capable of responding to its ambitious development goals. This was to be achieved via the partial centralisation and nationalisation of the electricity sector. The Electricity Supply Act of 1948 and the newly created Central Electricity Authority (CEA) were the first steps in the development of a state-owned and vertically integrated electricity industry (Pachauri, 1982: 198). They joined a broad set of tools underpinning the works of a highly centralised state, embodied in the National Planning Commission (established in 1950) and its Five Year Plans. Within the electricity sector the new model aimed only for a partial-centralisation, given constitutional mandates requiring resource management autonomy at the regional level. The Electricity Supply Act of 1948 complemented the CEA with State Electricity Boards (SEBs) operating at the provincial level, functioning as semi-autonomous regional bodies responsible for administering the grid. The establishment of SEBs was an attempt to adjust the centralised British model, which inspired India's electricity regime at the time, to the greater territorial scale of India. SEBs were directly controlled by state (provincial) governments, becoming the regional level agencies in charge of owning and rolling out electricity generation and transmission. The nationalisation of the power industry was consolidated when parliament adopted the Industrial Policy Resolution of 1956, the key economic policy of the coming decades, formally assigning electricity generation and distribution responsibilities to the state (Pachauri, 1982: 197).

Despite strong regional opposition to the idea of central planning, India's first three Five Year Plans (1951-1966) succeeded in the development of a solid and diversified industrial base. This was largely the result of their emphasis on power, irrigation and roads (Misra, 2007: 280-281). Business flourished while iron and steel production increased. Electric power and irrigation established the foundations for crucial industrial and agricultural strategies in the years to come.

Rural electrification, and through this an attempt to provide a form of electricity access for the majority of the population, defined the meaning of energy security in the country. Throughout the second half of the 20th century the Central Planning Commission established ambitious growth targets for the electric power sector. Generation capacity experienced a 13-fold increase between 1950 and 1979 such that "India's experience in power development, …despite many pitfalls and weaknesses displays a magnitude of growth almost unparalleled in the comity of the third world nations" (Pachauri, 1982: 189).

Regional power and the collapse of the 'electric' developmental state

The relative success of India's initial Five Year Plans, including the achievements of the electricity sector, was accomplished in the context of political distortions introduced by lobbying, vested interests and corruption (Misra, 2007: 281). Rent¬-seeking behaviour connected the local state and private interests, and SEBs were no exception. SEBs systematically underperformed at many levels, and the growth targets established by the Central Planning Commission were never fully achieved (Pachauri, 1982: 195). The multiple failures of the socio-technical networks powering the nation generated a scenario defined by chronically unmet demand, shortages, and planned electricity outages. Load shedding, a form of planned power shutdown stopping distribution in certain areas in order to respond to demand needs in others, became a standard energy management policy and the established mode of supply. Load shedding was designed in order to privilege rural over urban and industrial users (Smith, 1993: 385). Supply uncertainty clashed with the growing industry requirements, imposing additional costs to any form of industrial development. The industrial sector had no other option than to build its own parallel energy infrastructure, a phenomenon known as 'captive power', which in the 1970s and 1980s grew more rapidly than the formal utilities sector (Morris, 1996: 1276; Joseph, 2010).

As electric power became a populist tool to conquer the political allegiances of India's countryside in the 1970s, several factors contributed to the near collapse of the country's electricity regime (Morris, 1996: 1276). Financial mismanagement within SEBs became the norm, fostered by their high level of autonomy, limited financial accountability and poor economic efficiency (Pachauri, 1982: 198). A cross-subsidies system of electricity tariffs further exacerbated the negative financial condition of SEBs, whilst also favouring the agricultural sector to the detriment of industrial and domestic users (Morris, 1996). By 1994 electricity in the agricultural sector was on average 48% cheaper than its domestic counterpart, while industrial electricity was between 1.5 and 2.5 more expensive than domestic prices (Morris, 1996: 1278). At a time where the majority of Indian population lived in the countryside, subsidies for rural users played a key role in maintaining the political status quo by preserving voting allegiances. By the early 1990s it had become clear that "to charge farmers for more power would be an electoral disaster, and candidates in rural areas campaign on the promise of free cheaper electricity for farmers" (Smith, 1993: 386; see also Golden and Min, 2012). Through corruption and rent-seeking behaviour, regional political networks were capable of providing almost free electricity via illegal connections. Over time, the governing board of the SEBs became "a depository for political patronage to reward loyal party supporters; the managerial and other staff are subjected to political pressures on the award of tenders, electricity allocation, and jobs" (Smith, 1993: 385). The combination of subsidies and large transmission and distribution losses associated with illegal connections bankrupted the nation's electricity regime, while generating a culture of high-power intensity and low energy efficiency (Pachauri, 1982; Morris, 1996).

The near-collapse of India's electricity sector could be read as the result of its co-optation by regional political interests (Joseph, 2010). The history of electric power in the second part of the 20th century reflects the techniques by which regional powers resisted the governing efforts of the central state and established their own modes of governing. Whilst the central state retained the symbolic power of electricity and its infrastructure (via a modernising discourse that draws on infrastructure architecture (Misra, 2007: 302; Wyatt, 2005)), local and regional levels appropriated its material power to convert it into political power. For Nehru, dams were "the new temple[s] of resurgent India… the symbol of India's progress" (cited in Dharmadhikary and Sheshadri, 2005: 1). Yet, the power of such new temples was limited in the context of pre-existing political networks. Nehru's developmental state came under pressure as India's regions and localities – and their interest groups – found ways to resist the centralisation of power associated with the promised modernisation. Regional politicians competed with the national central nodes of command in Delhi for the control of key resources and their use in yielding power towards their own objectives (Misra, 2007: 291; Corbridge, 2009). Electric power was one of many silent domains of contestation. As regional politics worked under the logics of rural voters, the interests of urban dwellers were, with the exception of large metropolises, left out of the picture. Yet, as Chapter 5 explains, as India becomes more urbanised its infrastructure politics are to change.

2.3 Electricity at the turn of the century

The 1990s and early 2000s witnessed a reversal of the nationalisation efforts initiated in the 1950s, as deregulation emerged across the globe as a new dominant form for the configuration of electricity regimes. This section provides a brief account of the deregulation process of Brazil and India, alongside an overview of the electricity generation capacity in each country and a review of contemporary efforts to think about the electricity regime from the perspective of energy efficiency. These elements configure the contemporary energy landscape of both countries (Table 2.1), and provide and important context for the emerging local governance of energy. The in-built limitations of the centralised regime (examined in Section 2.2) resulted in a series of energy bottlenecks, crises and challenges. Triggered by these limitations, the idea of energy efficiency made an appearance in the policy agenda, gaining currency as a new way of thinking about energy. Since the turn of the century the electricity regime in place in both countries has been highly driven by the need to overcome significant limitations in generation and transmission.

	INDIA	BRAZIL
Basic data (EIA, 2013; data for 2010)	• ***Installed generating capacity:*** 208,000 MW. • ***Electricity sources:*** 70.7% fossil fuels, 19.5% hydro, 2.1% nuclear, 6.2% wind, 1.25% biomass and waste.	• ***Installed generating capacity:*** 113,000 MW. • ***Electricity sources:*** 19.6% fossil fuels, 71.4% hydro, 2% nuclear, 0.9% wind, 7% biomass and waste.

Sector structure and policies	• ***Responsibility:*** overall, the electricity sector is owned by the state, although structured in a corporate form. There is minor participation of the private sector in generation and distribution, and this is expected to grow.
	  • ***Ministry of Power:*** oversees electricity production and infrastructure development
	  • ***PowerGrid Corporation of India:*** responsible for the inter-state transmission of electricity and the development of national grid
	• ***Other relevant energy bodies:***
	  • ***Bureau of Energy Efficiency:*** statutory body under the Minister of Power
	  • ***Ministry of New and Renewable Energy:*** R&D, international cooperation, promotion, and coordination for renewable energy sources.
		• ***Responsibility:*** electricity sector fully deregulated with significant private ownership.
		  • ***Ministry of Energy and Mines:*** responsible for electricity policy.
		  • ***ANEEL:*** National Agency for Electricity, in charge of sector regulation and created as part of the deregulation process.
		  • ***Eletrobras:*** national energy company in charge of generating ~40% and transmitting ~69% of the country's electricity. It operates under combined public and private ownership, and the federal government has a 52% stake.
		• ***Other relevant energy bodies:***
		  • ***Power Research Company:*** statutory body under the MEM in charge of long-term integrated energy planning.

Key policies and legislation	• ***Electricity Act (2003) and National Tariff Policy (2006):*** unbundled generation, distribution and transmission sector and allowed for private sector participation; central and state electricity regulatory commissions to purchase a certain percentage of grid-based power from renewable sources.
	• ***Energy Conservation Act (2001):*** large energy-consuming industries are required to undertake energy audits; energy labelling program for appliances has been introduced.
	• ***Other relevant programmes:***
	  • ***National Energy Labelling Program (2006):*** energy-labelling program for appliances.
	  • ***PV feed-in tariff (2008):*** of 12 rupees (£0.12) per kilowatt-hour for solar photovoltaic power and 10 rupees (£0.10) per kWh for solar thermal power generation.
		• ***Law 9,648 (1998):*** establishes the main framework for electricity deregulation.
		• ***Law 9,991 (2000):*** mandated electricity utility companies to invest 1% of their net income in energy efficiency.
		• ***Energy Efficiency Law (2001):*** Law 10,295 and Decree 4,059, establishing specific consumption requirements for energy efficiency.
		• ***Electricity Act (2002):*** Law 10,438, providing guidelines for the diversification of the national energy portfolio and mandating universal access to electricity.
		• ***Other relevant programmes:***
		  • ***PROINFA (2002):*** National Program of Incentives for Alternative Electricity Sources.
		  • ***PROALCOOL (1973):*** National Alcohol Program, which developed Brazil's ethanol capacity through public sector subsidies and tax breaks.

Table 2.1: Summary of the contemporary energy landscape of India and Brazil

2.3.1 Overview of the electricity sector in India and Brazil

India has the 4th largest electricity generation capacity in the world, only surpassed by the United States, China and Russia. India's installed capacity of 208,000 MW almost doubles Brazil's, which, with 113,000 MW, ranks 8th. Figures from 2010 show significant differences in the electricity mix of both countries. As discussed in Section 2.2, Brazil's main electricity source is hydropower (71%), followed by fossil fuels (20%) and biomass and waste (7%). In an almost exact opposite way, India's main electricity source is fossil fuels (71%), followed by hydropower (19%) and wind (6%) (EIA, 2013b). Brazil consumes only 65% of the electricity consumed in India, although per capita figures tell a different story: on average, a Brazilian consumes four times as much electricity as an Indian (World Bank, 2013b).

Between 2006 and 2010 figures for electricity consumption show similar growth patterns in both countries, with a 20% growth in India and 19% in Brazil (EIA, 2013b). However, the realities of electricity use could not be more different. India has an overall electricity access rate of 75% (World Bank, 2013a). The large majority of this deficit is located in rural areas. In urban India electricity access is above 93%, but, with the exception of large metropolitan centres such as Delhi, Mumbai and Bangalore, service is non-continuous throughout the day as a result of load shedding. In contrast, Brazil has an electricity access rate of over 98% (World Bank, 2013a), and load shedding is not a common practice. The National Agency for Electricity (ANEEL) has imposed strict parameters regulating the frequency and duration of electricity interruptions (Queiroz, 2012). From an urban perspective, significant steps in the universalisation of service provision are being made through the regularisation of illegal electricity networks, which is being carried out by private energy suppliers and underpinned by the provisions of the Electricity Act of 2002 which requires the electricity sector to achieve 100% coverage. From a rural perspective, the federal government launched in 2003 the Light for All programme (*Luz para Todos*), with the goal of providing electricity access free of cost to over 10 million by 2008. It has been considered by some as the “most ambitious power inclusion programme implemented in the world” (Queiroz, 2012: 25).

2.3.2 Electricity deregulation

The 1990s witnessed a paradigm change in the electricity sector worldwide. The nationalisation trends of the middle of the century gave way to privatised and deregulated regimes. In the context of financial conditions associated with development loans imposed by the World Bank and the IMF, market-oriented electricity reforms were advanced in the global South. This new rationality for the provision of electricity services steps away from a vertically integrated structure and state-driven service, introducing private sector ownership and competition in an unbundled system of generation, transmission and distribution (Bacon and Besant-Jones, 2001). The stated drivers for this change are varied, ranging from the need to overcome a crisis of supply, management inefficiencies and a limitation of funds for investment, to a broader search for economic mechanisms capable of maximising benefits for society (Bacon, 1995). Yet, analysis of the effects of these reforms in developing nations points to mixed outcomes – on occasions accompanied by civil resistance – raising concerns about equity alongside negative impacts on energy access for the poor (Ghanadan, 2009; Williams and Ghanadan, 2006).

Brazil

Brazil started a deregulation process in 1996 with the aim of attracting private sector financing and limiting the tariff increases required for infrastructure expansion and maintenance (Estache and Pardina, 1999). Its efforts towards the privatisation of public utilities are rooted in macro-economic strategies aimed at attracting foreign investment to combat the country's excessive rates of inflation of the 1980s and 1990s. In the case of electricity, high operational costs and limited public finance, paired with the need for investments resulting from the growth of demand, led to a large-scale privatisation programme under the leadership of the central government, along with the Brazilian Development Bank (BNDES) and with the involvement of foreign multinational corporations (Estache and Pardina, 1999; Ventura Filho, 1996; Rosenblatt, 1996; Rudnick, 1996). Currently the sector is fully deregulated, with private companies acquiring ownership rights over generation, transmission and distribution via state auctions. Since 2001, in order to avoid future electricity crises, the government has put in place specific mechanisms offering long-term energy supply contracts to encourage private investments in generation (Batlle et al., 2010). However, the central state has maintained a large control of transmission (69%) and generation (40%) via Eletrobras, the national utility company in which the federal government has a 52% stake (OECD, 2008). As part of the deregulation process, Brazil created ANEEL, the electricity regulator, with the mission of "providing favourable conditions for the electricity market to develop in a balanced environment amongst agents, for the benefit of society" (ANEEL, 2013: 1; translated from Portuguese). ANEEL is under the authority of the Ministry of Energy and Mines (MEM), and is responsible for establishing the regulatory framework and control of generation, transmission and distribution. Overall planning and the development of strategic policy lies with the MEM, with the support of the Power Research Company, created in 2004.

India

In contrast to Brazil, deregulation in India has been a slower and unfinished process. The development of energy policy is predominantly controlled by the Ministry of Power, with the support of the Ministry of New

Renewable Energy. The Central Electricity Regulatory Commission (CERC), linked to the Ministry of Power, acts as the key regulator of the power sector with responsibilities for rationalising tariffs and subsidies. Deregulation started with the Electricity Regulatory Commissions Act of 1998, aimed at establishing a regulatory body in advance of the privatisation of distribution, and the largely unimplemented Electricity Act of 2003. Drawing from previous pilot experiences of deregulation at regional level supported by the World Bank, the Electricity Act of 2003 unbundled generation, distribution and transmission and allowed for private sector participation. However, the electricity sector is mainly owned by the state (provincial) level, albeit structured in a corporate form. There is minor participation of the private sector in generation and distribution, and it is expected that private sector involvement will grow over the decades of 2010 and 2020.

2.3.3 Multiple energy regimes operating in tandem

Formal electricity infrastructures (Figure 2.1) are not the only provision mechanism in India and Brazil, pointing to the presence of multiple energy regimes operating in tandem. Like in many other countries in the global South, a variety of formal and informal electricity infrastructures overlap (Section 3.2.1). Here they are described through the specific experiences of Thane and São Paulo.

Figure 2.1: Formal electricity provision in central São Paulo

São Paulo

Formal electricity provision in the State of São Paulo is largely in the hands of the privately owned Companhia de Transmissão de Energia Elétrica Paulista (CTEEP), which controls 80% of electricity transmission (CTEEP, 2013). Four privately owned companies share distribution: AES Eletropaulo, Elektro Eletricidade e Servicos SA, CPFP Energia and EDP Bandeirantes. The São Paulo Metropolitan Region is served primarily by AES Eletropaulo, which claims that 99.99% of the dwellings in the municipality have access to electricity (World Bank, 2012).

However, full access to electricity does not mean formal provision. Nearly a third of São Paulo's population lives in tenements (*cortiços*) or *favelas*, informal neighbourhoods established through illegal occupation. These are the main spaces of inequality in the city, with nearly 69% of households earning only up to one minimum salary and 34% earning less than half one minimum salary (UN Habitat, 2010).[3] Despite significant efforts for the regularisation of electricity infrastructures (Section 2.3.1), life in *favelas* is still characterised by irregular and precarious service provision, with patchy water and sewerage networks and electricity often accessed through illegal connections. Even as late as 2006, only 70% of the residents of the city's *favelas* and tenements were officially connected to the electricity grid (USAID, 2009). Informal connections are undersized for the amount of energy they are required to deliver, with constant voltage variations resulting in supply interruptions and damaged domestic appliances. They are also characterised by the use of improvised equipment, an absence of safety standards, fires and health hazards.

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[3] Compared to 32% and 10.7% respectively for those living outside *favelas* and tenements. Brazil's minimum salary, the legal minimum wage established by the government, is in the order of USD$300 per month.

Thane

In the case of Thane, the city is served by the Maharashtra State Electricity Board (MSEB). The Electricity Act of 2003 resulted in the unbundling of the MSEB in three state-owned companies for the purposes of generation (Mahagenco), transmission (Mahatransco) and distribution (Mahadiscom), with the MSEB remaining as the larger holding company. To secure supply, Mahadiscom is in charge of buying power from Mahagenco, from captive power plants or from other state electricity boards.

India's electricity deficit leads to engineered outages referred to as 'load shedding' (Section 2.3.1). In Thane, despite a Zero Load Shedding programme started in 2009 by the Maharashtra State Electricity Distribution Company Limited (MSEDCL), load shedding continues playing a role in the city's electricity make up. Under the programme users pay a surcharge on top of the electricity bill in order to ensure reliability. With the revenues collected through the surcharge, Mahadiscom buys power from sources outside the State and directs it to the cities involved in the programme (Mid-Day, 2009). The programme's success is limited, as a variety of factors stand in the way of Mahadiscom's ability to source power from outside the State. These include droughts limiting the availability of hydroelectricity, monsoon conditions increasing the humidity of coal and therefore reducing its efficiency, social conflict in neighbouring states affecting coal distribution, flooding events affecting power infrastructures (Daily News Analysis India, 2011; Times of India, 2011b), and most likely, a continuous increase in demand. By October 2011 it was estimated that the State of Maharashtra had an electricity shortage of between 3,500 MW and 4,000 MW of power, nearly 25% of its total demand. Following from a brief period of reliable electricity supply, load shedding was reinstituted in Thane in October 2011 (Times of India, 2011a; Daily News Analysis India, 2011).

Like São Paulo, both Thane and the Mumbai Metropolitan Region are characterised by a significant number of informal electricity connections (Figure

2.2), particularly in the city's slums. However, this is not the only alternative form of provision. Load shedding has historically trigged formal and informal electricity users to develop their own localised energy management and supply strategies. For decades industrial users have relied on what is known as 'captive power': private and off-grid medium scale generation facilities (Section 2.2.2). Residential and commercial users rely on oil and diesel generators (Figure 2.3) as well as inverters: a battery pack paired with a DC/AC inverter that is activated automatically when the main power is switched off (Figure 2.4). The inverter provides enough energy for a few lights and other basic electric equipment such as a computer for a few hours until the main electricity supply is restored.

Figures 2.2 and 2.4: Informal electricity connections in Ghatkopar, Mumbai and invertor and battery pack for residential electricity provision, Thane.

Figure 2.3: Private diesel generator for electricity provision, Thane.

2.3.4 The challenges of the electricity regime and the rise of energy efficiency

The biggest challenge facing the electricity regime in both countries is related to the ability to maintain supply in the face of rapidly growing demand. The historic make up of energy infrastructures in both countries (Section 2.2) has led to a limited degree of flexibility alongside high reliance on electricity. In the case of India, the growing gap between demand and supply threatens the country's ability to maintain the rapid economic growth characteristic of recent years. In Brazil, the possibility of large-scale blackouts has led to a reformulation of the country's energy strategy. The result in both countries has been a renewed emphasis on issues of energy efficiency.

India: rapid economic growth in the midst of a gap between supply and demand

India's electricity sector is characterised by a significant gap between available supply and existing demand. For the year 2013-2014 the government expects this gap to be 6.7% of the total energy required in the country (Government of India, 2013). In 2006 India's Planning Commission evaluated the country's energy needs required to maintain an annual GDP growth of 8%. According to their results electricity generation capacity would have to be increased from 160,000MW at the time to 800,000 MW by 2032, a staggering five-fold increase in 25 years, serving an estimated peak demand of 592,000MW. The capacity required for serving under half of such peak demand (323,000MW) would need to be in place by 2022 (Government of India, 2006: 20). Less conservative estimates suggest that such peak demand levels are likely to be reached as soon as 2017 (McKinsey & Company, 2008: 28; see Figure 2.5). India's rapid urbanisation rate plays a significant part in this challenge given the greater energy consumption associated with urban life (Section 5.3.1).

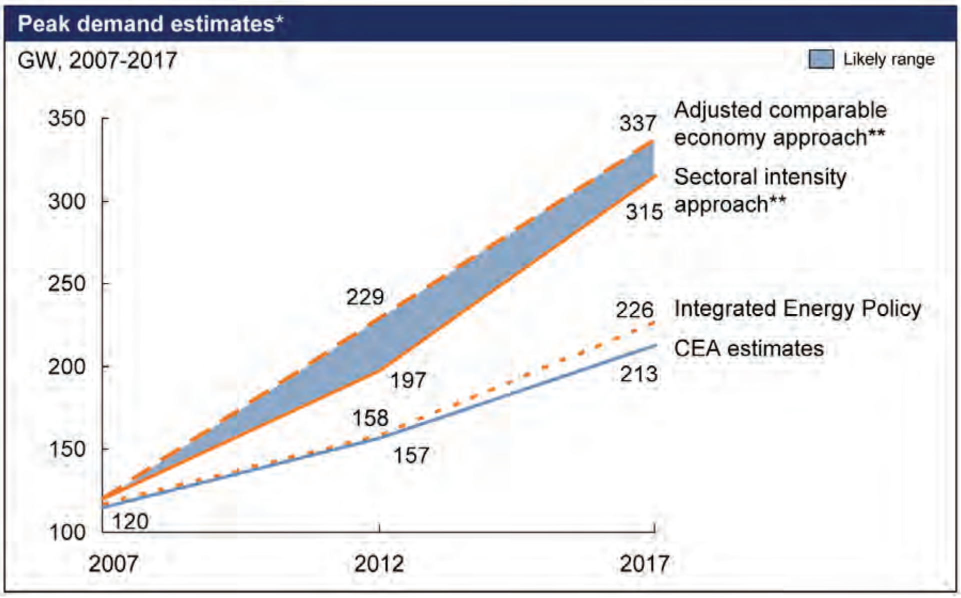

Figure 2.5: Peak electricity demand estimates to 2017, India (McKinsey & Company, 2008: 28).

In light of these challenges, in 2001 the Government of India passed the Energy Conservation Act. The Act created an energy labelling system for appliances, required large energy consumers to adopt efficiency measures, and established the Energy Conservation Building Code. It also created the Bureau of Energy Efficiency, a statutory body under the Minister of Power for the implementation of efficiency initiatives. In 2009 the government adopted the National Mission on Enhanced Energy Efficiency (NMEEE), as part of the National Action Plan for Climate Change (NAPCC), as a way to strengthen and channel resources to the Bureau of Energy Efficiency. The NMEEE is based on the roll out of awareness programmes and a multiplicity of financial and market based mechanisms. It is expected to save 5% of India's energy consumption by avoiding generation capacity of 19,000 MW.

Brazil: black-outs and extreme peak loads

Since the turn of the century Brazil's electricity strategy has been largely dominated by the spectrum of shortages, particularly since the 2001-2002 "black out crisis" (in Portuguese, *Crise do Apagão*). Shortages are the result of the country's dependence on hydropower in the midst of unpredictable weather cycles, along with historically developed high levels of consumption. In mid-2001 Brazil's electricity regime entered a state of shock as the government was forced to draft nationwide plans for planned electricity outages of up to 5 hours a day, aiming for a reduction of 20% in total electricity consumption. The crisis has been blamed on an extended drought affecting the reservoirs feeding the nation's hydroelectric system, along with lack of planning and limited investment in the electricity sector in the preceding decades (Soares and Rocha Souza, 2003).

This experience of power outages and government-mandated energy rationing was overcome in early 2002. This was thanks to a change in rainfall patterns, alongside a successful programme of 'voluntary' reductions in electricity consumption via tariff incentives and steep penalties attached to a reduction of 15% to 25% in electricity consumption for all customers. The rationing led to an 8% reduction in electricity consumption for the year 2001 (Figure 2.6) (Carreno et al., 2006). This experience triggered a series of actions aimed at reducing electricity use and increasing energy efficiency. Even before the crisis, the Brazilian electricity sector had already considered strategies for energy efficiency although with only limited success. Throughout the 1980s, and largely in response to the energy crises of the 1970s, energy conservation started to play a more prominent role in Brazil. Between 1984 and 1985 the Brazilian government created the country's first energy labelling programme, the Brazilian Labelling Programme and the National Electricity Conservation Programme (PROCEL) (both discussed more in detail in Section 6.3.2). This early interest in energy conservation faded with the introduction of electricity deregulation in the early 1990s (de Martino Jannuzzi, 2000). Rationalities around energy efficiency entered the policy agenda again in the early 2000s, when the government launched the Energy Efficiency Law, a national policy for energy conservation, regulating maximum consumption and minimum efficiency levels for all equipment (*Lei 10.295 de 17 de Outubro de 2001*). In parallel, ANEEL supported the development of legislation mandating private electricity utility companies to invest 1% of their net income in energy efficiency projects (*Lei 9,991 de 24 de Julho de 2000*). With the socially-minded government established by President Lula this energy efficiency agenda was linked to social policies and poverty reduction programmes (Section 5.4.1). In 2007 the Ministry of Mines and Energy published the National Energy Plan 2030 (Governo Federal do Brasil, 2007) which incorporated energy efficiency as a key strategic driver and mandated the development of a National Energy Efficiency Plan (NEEP). Published in 2010, the NEEP aims to reduce 10% of energy demand by 2030 (Governo Federal do Brasil, 2010b).

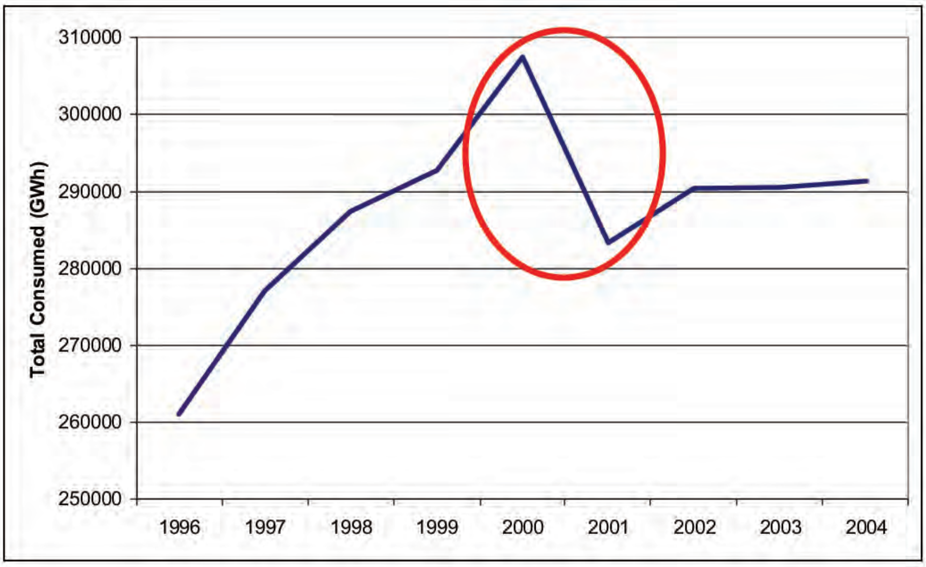

Figure 2.6: Electricity consumption 1996-2004, Brazil (Carreno et al., 2006: 4).

In addition, as discussed in more detail in Chapter 5, Brazil's electricity demand curve suffers from a steep daily peak demand that imposes supply constraints, testing the limits of generation and transmission capacity. This daily peak demand is largely associated with the socio-cultural practice of using electric showers, responsible for 6% of the total electricity consumption of the country and 18% of the peak demand. Under current projections, it is expected that by 2030 electric showers will be responsible for a demand of 6,500 MW (Governo Federal do Brasil, 2010b), a significant load for a country with a current total installed capacity of 113,000 MW.

2.4 Further electricity problematisations: climate change

The final section of this chapter provides an overview of issues of climate change in India and Brazil, and illustrates how climate change has started to play a role as one of the key themes framing each country's electricity agenda. Climate change policies and discourses have begun to justify further development of non-fossil fuel-based electricity regimes, acting as one of the key domains where a multiplicity of initiatives promoting renewable systems and technologies – e.g. solar – are developed. The section finishes with a reflection on the interface between the climate change and urban agendas, and how this interface is operating specifically in São Paulo and Thane.

2.4.1 Climate change agendas in Brazil and India

Dominant energy regimes, primarily through a large dependency on fossil fuels, are responsible for the majority of greenhouse gas emissions (GHG) causing global warming. In 2009, Energy related emissions (including industrial processes but excluding aviation and maritime transport) accounted for 75.2% of the total GHG emissions of the world (World Resources Institute, 2013). India and Brazil are amongst the highest GHG emitting countries. Data for 2009 shows India in the 3rd position with 5.47% of the world's total and Brazil in the 6th position with 2.5% (Table 2.2). However, largely due to Brazil's decarbonised hydroelectric energy matrix, alongside the country's ethanol fuel programme established four decades ago, electricity and heating emissions for both countries (within the energy sector) present a contrasting scenario. India is responsible for 6.8% of global energy related emissions, ranked 3rd, whilst Brazil is responsible for 0.43% ranked 32nd (World Resources Institute, 2013) Emissions in both countries are predicted to grow significantly between 2010 and 2040, with a 2.3% annual growth in India (the highest in the world) and 1.8% annual growth in Brazil (EIA, 2013a: 162). Their 2009 per capita emissions vary significantly, with Brazil slightly below half the global average at 1.95 tCO_2e per year and India appreciably below the global average at 1.43 tCO_2e per year (global average: 4.60 tCO_2e).

	INDIA	BRAZIL
Emissions *(World Resources Institute, 2013; data for 2009 data, excluding LUCF)*	• ***GHG emissions:*** 2,332.8 MtCO2e; global rank: 3 • ***GHG emissions/capita:*** 1.43 t/yr; global rank: 119 • ***Population/emissions ratio:*** 17% of the world's population / 5.47% of the world's GHG. • ***2010 - 2040 emissions growth pattern:*** 2.3% average annual growth; 96% total growth.	• ***GHG emissions:*** 1,066.5 MtCO2e; global rank: 6 • ***GHG emissions/capita:*** 1.95 t/yr; global rank: 104 • ***Population/emissions ratio:*** 2.8% of the world's population / 2.5% of the world's GHG. • ***2010 - 2040 emissions growth pattern:*** 1.8% average annual growth; 71% total growth.

Relevant Policies	• ***National Action Plan on Climate Change (NAPCC, June 2008):*** includes 8 missions associated with this initiative, such as:
	  • *National Solar Mission* (20,000 MW of solar power by 2020).
	  • *National Mission for Enhanced Energy Efficiency* (10,000 MW of EE savings by 2020).
	  • *National Mission on Sustainable Habitat* (promoting energy efficiency in urban planning).
	  • *National Mission on Strategic Knowledge for Climate Change* (vulnerability assessment, research & observation, data management).
		• ***National Policy on Climate Change (NPCC, December 2009):*** signed as law 12,187, establishing voluntary GHG reduction targets (see below).

Targets	• ***National Policy Targets (NAPCC, 2008):*** avoidance of establishment of defined targets. Commitment that Indians' emissions per capita will not exceed those of people in developed countries. • ***Target submitted to the Copenhagen Accord (January 2010):*** "to reduce the emission intensity of its GDP by 20 to 25% by 2020 in comparison to the 2005 level. The emissions from the agriculture sector will not form part of the assessment of emissions intensity." (Announcement by the Indian Environmental Minister, cited in Climate Action Tracker, 2013).	• ***National Policy Targets (December 2009):*** GHG reduction of between 36.1% and 38.9% by 2020 (against an estimated 'business as usual' level), conditional to international financing. Achieving the target depends primarily on reducing deforestation rates. • ***Target submitted to the Copenhagen Accord (January 2010):*** as above.

Table 2.2: Summary of climate change policies and basic data for India and Brazil.

Brazil has introduced voluntary GHG reduction targets of between 36.1% and 38.9% of projected emissions by 2020 (*Lei 12,187, de 29 de Dezembro de 2009*). These targets are part of the country's National Policy on Climate Change (NPCC), launched in 2009. In contrast, India has historically refused to adopt GHG reduction targets, limiting its commitment to reducing the emissions intensity of its GDP by 20-25% by 2020 (against a 2005 baseline). These commitments have significant implications for both countries' energy and electricity generation strategies and paths for resource consumption. In 2008 India published its first

National Action Plan on Climate Change (NAPCC). The plan includes eight core "national missions" running through to 2017. These include a National Mission for Enhanced Energy Efficiency, a National Water Mission (targeting a 20% improvement in water efficiency) and a National Mission on Strategic Knowledge for Climate Change. India's NAPCC purposefully sets out to promote solar energy via the National Solar Mission (Section 2.4.2).

2.4.2 Renewable responses in the electricity regime

Both India and Brazil are developing programmes and initiatives aimed at increasing electricity generation capacity via renewable sources. Whilst this is framed by climate change concerns, it also responds to a variety of strategic drivers such as the need to increase energy security, diversify energy sources, and foster economic development. Data for 2010 shows Brazil with an installed electricity capacity of 8,700 MW coming from non-hydroelectric renewable sources, representing a 7.7% of the total. The majority of this is biomass and waste (7,800 MW), followed by wind (900 MW). In the case of India, the installed capacity coming from renewables is 15,700 MW, 7.5% of the total. The majority of this is wind (13,000 MW), followed by biomass and waste (2,600 MW). Growth in the renewable sector is occurring more rapidly in India than in Brazil. Between 2006 and 2010 non-hydroelectric renewable capacity grew by 112% in India, compared to only 34% in Brazil (EIA, 2013b).

In 2002, Brazil instituted the National Programme of Incentives for Alternative Electricity Sources (PROINFA). By focusing on wind, biomass and small hydro generated by 'independent producers', the programme aimed to increase the share of non-hydroelectric renewable sources by 3,300 MW by 2010. Electricity generation via solar photovoltaic systems has not received significant support in Brazil, and accounts for less than 0.01% of the total. In contrast, India is rapidly developing its solar sector. As part of the NAPCC it announced the Jawaharlal Nehru National Solar Mission (JNNSM), with plans for over 20,000 MW of new solar generation by 2022. Support for the development of solar capacities in India has occurred via the promotion of feed-in tariffs for grid connected mid-scale solar PV projects.

Both countries have programmes and strategies promoting SHW. In India, the JNNSM proposes the installation of 20 million m^2 of solar thermal collectors for water heating by 2022. For this purpose, in June 2010 the MNRE established a subsidies system that allows manufacturers to claim back 30% of the value of each unit sold. It has been claimed that the JNNSM is responsible for doubling the total amount of collector area installed in India, from 3.5 million m^2 in 2010 to 7 million m^2 in 2013 (Global Solar Thermal Energy Council, 2013). In Brazil, the NEEP dedicates one chapter to the achievement of energy efficiency via SHW. The plan lays the foundation for a program to accelerate the use of SHW in Brazil, and prioritises SHW investment within federal resources destined towards energy efficiency (Governo Federal do Brasil, 2010b). One of the primary ways in which the Brazilian government supports the development of the SHW industry is through scaling up SHW use in government funded social housing programmes. This will be discussed in greater detail in Chapters 5, 6 and 7.

In spite of sharing an objective around the promotion of SHW, the figures quoted in the previous paragraphs illustrate two markedly different renewable energy paths. In the case of Brazil, renewable energy development plays an important role in increasing flexibility by diversifying the country's highly hydropower based electricity regime. Brazil's slower uptake of renewables is partly the result of its already highly decarbonised matrix, alongside a significant biofuels capacity aimed at both national and international markets. The biofuel industry has led to the use of bagasse for electricity generation, initially aimed at powering the needs of the ethanol production process but more recently directed to grid-connected thermal plants. It has been estimated that by 2015 grid electricity generated via bagasse may reach 15,000 MW (Pereira et al., 2012). In the case of wind power, high costs have historically been considered an obstacle for its development, particularly when evaluated side by side with the unexplored potential and lower costs of hydroelectricity. PROINFA's recent investments in wind have resulted in lower costs and an interest by multinational companies in establishing turbine manufacturing plants (Pereira et al., 2012). In the case of solar PVs, the lack of manufacturing abilities plays a role in the minimal growth of this sector. The current use of solar PVs focuses on non-grid connected services, primarily towards pumping systems or rural electrification.

In the case of India, renewable energy functions as a strategy for both economic development and energy security. Its development is currently under the leadership of the private sector, backed by strong state subsidies, finance and the creation of a favourable investment climate. This is complemented by a significant involvement of the multilateral banking sector (via World Bank and Asian Development Bank) in the promotion of public private partnerships for renewable energy. Whilst the NAPCC links renewable energy with the need to decarbonise the economy, there is a clear prioritisation of national development goals over potential climate change mitigation (Newell et al., 2011). The Clean Development Mechanism plays an important role in funding renewable energy projects. However, "renewable energy projects in India are increasingly attractive to investors on a risk return basis, independent of carbon finance" (Phillips and Newell, 2013: 657).

The prominence of wind power in India is the result of the early development of capabilities (including manufacture), via the Wind Power Programme established by the central government in the 1980s. The current programmes for the promotion of solar PVs are aimed at the development of grid-connected electricity primarily via large solar farms, aiming also at the development of manufacturing capacity. These developments occur under private sector leadership, although they rely on financial and fiscal incentives at state level, including feed-in-tariffs, low interest loans, accelerated depreciation and tax exemptions. (Phillips and Newell, 2013).

2.4.3 The interface between the climate change and urban agendas

To conclude, this section provides contextual information on the interface between climate change and cities, with an emphasis on its empirical dimensions (see also Section 3.2.2 for a more conceptual discussion on the topic).

Scholars working on the cities and climate change interface often point to the difficulties faced by cities in integrating global environmental concerns into local environmental agendas (Betsill, 2001). When drawing responses to climate change, cities have to balance climate initiatives with a diverse set of drivers in their local governance regimes. This is particularly relevant for cities in the global South, where climate change agendas compete with, for example, issues of poverty alleviation, infrastructure provision and environmental health (Bulkeley et al., 2009; Holgate, 2007; Romero-Lankao, 2007b). Cities in rapidly industrialising countries such as Brazil and India are characterised by rapid economic growth, recent or predicted rapid population growth and large scale investment plans in their urban infrastructures for decades to come. They experience a tension in their dominant development model, where local economies, travel needs and energy consumption grow exponentially within the context of national and regional energy frameworks prescribing that such demands are likely to be meet via fossil fuels (Bulkeley et al., 2009). Similarly, local authorities in the South often find themselves at odds with striking a balance between climate adaptation and mitigation investments, as the latter can be perceived as a limitation for economic growth or conflict with other local agendas (Lasco et al 2007, cited in Bulkeley, 2010).

Analyses of the ways in which cities in the South are responding to climate change have placed significant attention to the specificity of southern urban processes, with an emphasis on shortcomings in institutional capacity and the pre-existing weaknesses of local governace regimes. These perspectives rightly avoid overstressing the industrial and technological aspects of dealing with climate change, and conterbalance popular approaches that emphasise notions of ecological modernisation. The resulting approach considers social agendas, the existing wealth disparities between the rich and the poor, and the need to develop 'good governance' as a pre-requisite for climate responses (Romero-Lankao, 2007a; 2007b). However, little attention has been placed on the socio-technical dimensions involved in making urban climate responses, and the ways in which different social, political and material configutarions of infrastructures are likely to potentialise or limit such efforts (Bulkeley et al., 2009: 8; see Section 3.2.2).

Overall, cities in developing countries tend to have a much lower level of GHG per capita than their developed counterparts. This is the result of low levels of industrialisation, low levels of private car use, and limited ownership of electrical equipment in homes and business (Satterthwaite, 2009). For example, a comparative study of the per capita carbon footprint of 12 large cities worldwide found the footprint of Delhi, Manila and São Paulo to be under 1.15 $MtCO_2e$, compared to the footprints of New York, Singapore and Los Angeles all of which are close to 2 $MtCO_2e$ and beyond (Sovacool and Brown, 2010). The relatively high levels of emissions per capita of certain cities in middle-income countries and rapidly industrialising societies are largely associated with their industrial activity, although often this industrial activity corresponds with the production of goods that – within their life cycle – are consumed in cities of the industrialised world (Satterthwaite, 2009; see also Hoornweg et al., 2011; Harris, 2013). Thus, thinking about climate change in cities of the South necessarily raises issues of climate justice on a global scale, pointing to the need to acknowledge differentiated international responsibilities in relation to global warming (Baer et al., 2008). Yet, issues of climate justice also need to be considered within the city, a topic that has been neglected in the academic literature (Bulkeley et al., forthcoming).

Both energy demand and GHG emissions are rapidly growing in the southern city (Bulkeley, 2013: 9). In the context of the international climate change regime, São Paulo and Thane are examples of major urban nodes within two large developing nations which, within a post-Kyoto architecture, are increasingly under pressure to commit to GHG reductions via binding targets

(Olmstead and Stavins, 2012). Emissions in the city of the global South, rather than solely responding to issues of industrialisation (or population growth), are also the result of rapidly chaging consumption patterns (Satterthwaite, 2009). As large cities in middle-income nations increase industrialisation and improve the coverage of networked infrastructures, both energy use and GHG emissions are likely to rise. This highlights the crucial need to address mitigation issues in cities of middle-income countries. The remaining part of this chapter introduces issues of climate change in Thane and São Paulo, further examined in more detail in 5.3.3 within the context of the emerging local governance of energy.

São Paulo

Both the State and city of São Paulo have pioneered the development of policies and action plans in response to climate change. The municipality of São Paulo has been experimenting with different mechanisms to respond to climate change since 2005, when it became one of the first Brazilian cities to publish a GHG emissions inventory (Prefeitura do Município do São Paulo, 2005). São Paulo launched in 2009 its Climate Change Policy (CCP), followed by the city's Climate Change Action Plan (CCAP) in 2011. The city's CCP explicitly recognises the United Nations Framework Convention on Climate Change, while establishing an ambitious target of reducing 30% of the city's emissions by 2012 (against a 2003 baseline). The State of São Paulo has also taken active steps to address climate change, including a state level Climate Change Policy and a GHG inventory (Governo do Estado de São Paulo, 2011).

Despite these initiatives, GHG emissions have been on the rise. In 2003 the per capita emissions of the city of São Paulo were 1.47 tCO_2e, for an emissions total of 15.7 million tCO_2e (Prefeitura do Município do São Paulo, 2005). For the period 2003-2009 the latter figure was 16.4 million tCO_2e, an increase hailed by the media as a failure to achieve the 30% reduction established by the city's 2009 Climate Change Policy (Agência Brasil, 2013). Residential electricity consumption was one of the main factors behind the increase in GHG emissions, showing a 33% increase (Geoklock / EKOS Brasil, 2013). The 2003 data shows how energy use for transport and electricity is responsible for most of São Paulo's GHGs, accounting for over 75% of the total, followed by solid waste disposal, at about 23%. Despite the dominance of hydropower in Brazil's electricity matrix, electricity use still makes a substantial contribution to greenhouse gas emissions. Out of the total emissions related to energy use in the municipality, 11% correspond to electricity (Prefeitura do Município do São Paulo, 2005). Whilst at the city level, the primary strategy for responding to climate change has been related to transport interventions, both state and municipal levels see SHW as an important mechanism for implementing a low carbon urban infrastructure. This will be explored in more detail in Chapters 5, 6 and 7.

Thane

Thane was one of the first Indian cities to engage with issues of climate change. The city completed its first GHG inventory in 2008, funded by the British High Commission and implemented by ICLEI-Local Governments for Sustainability, a global network of local authorities working on climate change since 1991. This study established Thane's per capita emissions at 1.15 tCO_2e (ICLEI, 2009). These figures were updated with the publication of the city's Solar City Masterplan (ICLEI, 2011). Just like in São Paulo, both GHG emissions and electricity consumption in Thane have been on the rise, with a 20.8% increase in emissions and an 18.1% increase in electricity over the three years preceding the publication of the Masterplan (ICLEI, 2011).

Thane's main source of GHG emissions is electricity (74%), followed by transport (14%). Residential and industrial activities are the source of the majority of electricity emissions. However, growth trends show a rapid increase in residential and commercial emissions, reflecting the changing nature of the city from an industrial to a residential node. Between 2004 and 2008 electricity consumption grew by 57% and 100% in the residential and commercial sectors respectively, compared to only 10% in the industrial sector (ICLEI, 2008).

2.5 Summary

Throughout the 20th century, electricity was conceived and acted upon in a multiplicity of ways. In Brazil and India, its urban origins soon gave way to national level strategies concerned with issues of modernisation, economic development and industrialisation. Over the course of the 20th century, beyond being a catalyst for development, electricity infrastructure "became an essential focus of the power, legitimacy and territorial definition of the modern nation state" (Graham and Marvin, 2001:74). The electricity regime established in the mid-20th century was characterised by state ownership and a centralised nature as much as by a function around controlling territory. In both countries, electricity infrastructure was instrumental for the nation's security and development aspirations, and thus strategic enough for it to be in the hands of the central state. However, there are key differences in the way that this emerged in each context. In India, after British independence, the early electrification of cities gave way to an understanding of electricity primarily as a tool for the benefit of the rural countryside (Smith, 1993; Morris, 1996). In Brazil, whilst the ability to supply energy to the city still acts through the century as relevant driver, the economic development model characteristic of the mid-20th century links the fates of electricity and industrialisation, thus reconfiguring the energy problem primarily within the domains of industrial growth and national development (De Oliveira, 2003). Further, the success by which they were able to deliver the much-needed electric power differed with the ability of the central state to secure control over regional and local geographies. Brazil's command and control approach to electricity, via central planning and hydroelectric technologies, secured regional buy-in. In contrast, India's politicised grid is a representation of regional and local powers taking over the energy regime to the benefit of their own objectives, yet threatening the effective delivery of electric power.

In the 1990s, after almost half a century in state ownership and centralised control, electricity regimes went through a significant transformation, as they embraced new rationalities around deregulation and liberalisation. This process, still under development, opened the regime to private stakeholders and separated its key components: generation, transmission and distribution. In parallel, a gradual unfolding of crises gave rise to new ways of understanding energy, particularly as an exclusively supply-based model gave way to the consideration of demand via energy efficiency. Again, responses to deregulation models and crises show significant differences in the way electricity is governed in the two countries. The move towards privatisation remains more precarious and unfinished in India than in Brazil, although India is posed to support an increase in privatisation in the years to come. In Brazil, an energy crisis at the turn of the century results in a declaration of a national emergency and the modification of consumption patterns across the country. In India, through load shedding, forms of crisis management have been incorporated into the everyday functioning of the system. Those cities that are experimenting with ways of avoiding load shedding, such as Thane, are doing so based on their ability to pay by charging premium prices to customers. These differing historical contexts, together with differing socio-technical responses to and engagements with the rationalities circulating at the global and national levels, establish contemporary arrangements within which cities are responding differently to new challenges and crises in the twenty first century.

The turn of the century brought about a new form of problematisation: climate change and the need to transform energy infrastructures towards low carbon systems. Both countries set out to implement different renewable energy regimes: Brazil's has been based primarily on biomass (drawing on its historic capacity around biomass) and India's on wind and grid-connected solar PV farms (aimed at developing and expanding manufacturing capacity). The city figures little in such national energy strategies. Yet, in this scenario, the city can be seen as both the problem and the solution (Bulkeley, 2013). Thane and São Paulo set about to respond to this challenge in a multiplicity of ways. Through inventories and policies, they incorporate climate change into their accounting practices and policy strategies. This opens up ways of thinking about the city too, as a scale through which differences in the engagement with electric rationalities occur. How they do this, specifically in the context of energy – and through SHW technologies – is the subject of Chapters 5, 6 and 7.

Chapter 3

Understanding the changing relations between energy, urbanism and governance

3.1 Introduction

This chapter presents and discusses the thesis' conceptual framework. This is done in two distinct steps. First, the chapter examines the scholarly literature on urban infrastructures developed within human geography – and associated disciplines – placing a particular emphasis on energy infrastructures (Section 3.2). This literature review lays down analytical foundations for the thesis. Second, drawing on Foucault's analytics of governmentality (Foucault, 2009), the chapter presents an alternative framework for the study of the social, political and governance implications of the transformation of energy infrastructures in the city (Sections 3.3 to 3.6).

Using an analytics of governmentality as a tool for understanding the transformation of energy infrastructures allows the thesis to unpack the emergence of a different energy regime in the city. This is composed of new ways of thinking about the energy problem, a variety of mechanisms aimed at governing energy locally, and the introduction of a new set of energy subjectivities. The conceptual framework draws primarily on the work of Dean (2010), Legg (2007b; 2011) and Li (2007a; 2007b), combining the three different configurations of governmentality developed by these authors. The notion of regimes of practices of government (also referred to as regimes of government) plays a key role in the framework, and is understood as routinised and "organised ways of doing things" within the governing efforts (Dean, 2010: 27). However, approaching such regimes is done through the vocabulary offered by the notion of assemblage (Li, 2007a), as a way of emphasising the contingency and messiness intrinsic to the activity of governing. In addition, emphasis is placed on governmental rationalities, as the ways of thinking about energy and its transformation; governmental techniques, as the material and discursive means by which the transformation occurs; and subjectivities, as the energy identities that are configured in the process of governing (Dean, 2010; Legg, 2007b; Li, 2007a). These three key analytical building blocks are complemented by an engagement with the role of material technologies in framing the relationships between the governing efforts and the resistances involved in improving urban infrastructures. Finally, notions of scale and territory are considered, providing conceptual entry points for understanding the reterritorialisations that occur as the city becomes a key site for the problematisation of energy regimes and the identification and development of solutions.

In developing the conceptual framework of the thesis, theory is approached as an interpretive device. In other words, rather than a system of thought, theory is seen as a research tool for critically questioning a reality (Foucault, 1980: 145). The field of renewable energy is characterised by an abundance of voices (of national governments, NGOs, industry players and international organisations, amongst others) already claiming a stake in the definition of the 'optimal' ways for increasing local and renewable energy systems. In such scenario, a critical analysis of the emerging local governance of energy must begin with the recognition that such transformation "may lead to the formation of new alignments and divisions and new relations between [expertise] and political action and, as a result, may demand new ways of thinking about politics" (Barry, 2006: 244). This opens possibilities for exploring the ways in which decentralised renewable energy interventions shift power between the city and the central state, promote more or less progressive urban politics, and generate possible alternative understandings of urban infrastructure. In this sense, theory operates as "a disruptive force, a deconstructive tactic, a denaturalising strategy, or a diffractive lens through which to view afresh a particular set of problems… usually taken for granted" (Gulson and Parkes, 2010: 78). Drawing on Foucault's critical spirit, an analytics of governmentality is used to rethink the environmental and resource politics of the city, understanding how things are *made* – rather than *found* – and thus opening possibilities "for them to be *unmade*, or *made differently*" (Rutherford, 2007: 305, original emphasis).

3.2 Understanding electricity in the city

In inquiring about the work energy does in the city, as a prerequisite for evaluating how a transformation in energy regimes affects broader social, political and urban governance processes, this section engages with three questions. They are, first, how do energy infrastructures configure the urban? Second, what agencies are enabled – or disabled – by energy infrastructures, particularly in the context of urban sustainability debates? And, third, how do certain forms of user interface foster specific understandings of the city and its infrastructure? Examining these questions through a body of literature familiar to human geography, particularly within urban infrastructure studies, provides a starting point for this inquiry. It illustrates key concepts for the study of the transformation of energy regimes, identifying limitations and points of tension, and provides the basis for the formulation of alternative conceptual framings.

3.2.1 Energy infrastructures and the configuration of the urban

The first question asks how energy infrastructures configure the urban. In broad terms, according to the literature reviewed, this occurs in three ways. As a key networked infrastructure, energy underpins the possibility of a unified and modern city, and by the same token, it can create fragmentation and spaces of exclusion (Graham and Marvin, 2001). Operating as a symbolic device, energy infrastructures support visions and ideals for the future of the city (Nye, 1999; Graham and Marvin, 2001). Finally, through their integration with water systems and their reliance on water and other natural resources – such as gas, coal and even sunlight – energy infrastructures act as mediators between nature, society and the city (Monstadt, 2009; Kaika and Swyngedouw, 2000). Intervening in energy infrastructures, through (for example) the promotion of more sustainable energy infrastructures such as solar systems, has an impact on how resources are distributed and by whom they are accessed, and therefore must be considered political (Swyngedouw, 2006; McFarlane and Rutherford, 2008).

Electricity networks and the creation of urban fragmentation

Networked infrastructures shape both spatial and political dynamics in the city. Between 1880 and 1960 electricity networks in the western world were instrumental in the emergence of the modern ideal of service access and urban cohesion. The integrated networked city, where electricity, gas, transport and communication networks readily service all citizens, became the standardised norm and the dominant rhetoric in urban planning, thus mobilising reason and democracy towards particular urban forms and the fulfillment of collective goals (Graham and Marvin, 2001: 62). Yet, the privatisation and liberalisation of utilities characteristic of the second part of the 20th century resulted in processes of 'urban splintering' rather than integration. Electricity and other infrastructure networks, seen by planners, engineers and architects throughout the century as the integrators of urban space, were reconfigured as specialised, privatised and customised, providing increased connectivity to some while bypassing others. The resulting trend encouraged the fragmentation of the socio-material fabric of the city and exacerbated spatial segregation and social polarisation, raising questions about the existence of the city as a whole (Graham and Marvin, 2001). Infrastructure connections and access were revealed to have an uneven distribution in response to different political and economic interests and capacities, alongside a "paradoxical trend towards the reinforcement of local boundaries" (Graham and Marvin, 2001: 9). This splintering urbanism signals the collapse of the modern infrastructural ideal of the integrated networked city.

In the global South, where the realisation of a modern infrastructural ideal has been highly uneven (Coutard, 2008), urban infrastructures have also played a role in the generation of spaces of injustice and exclusion. Southern cities have always been characterised by fragmented urban fabrics and infrastructures in a permanent state of disrepair and improvisation (Graham and Thrift, 2007: 11; McFarlane and Rutherford, 2008: 370). The development of infrastructure networks has been "socially constructed by various interest groups through an array of tensions, tactics and complexities, which are far more problematic for (just and equitable) infrastructure provision than any technical issues" (McFarlane and Rutherford, 2008: 370).

Infrastructure in cities in the South is "'splintered' rather than 'splintering'" (Kooy and Bakker, 2008: 1843), characterised by 'incomplete modernities' and with service provision historically concentrated on the wealthy (Gandy, 2006: 374). For example, research from Mumbai (Zerah, 2008) highlights the limitations of applying the splintering urbanism thesis (Graham and Marvin, 2001) to cities in the South, by pointing to the ways in which infrastructure provision is "distorted in favour of the elites" (Zerah, 2008: 1922). Rather than based on a single unified network, infrastructure is characterised by a multiplicity of – formal and informal – provision mechanisms that makeup "spatially separated but linked 'islands' of networked supply" (Bakker, 2003: 337). In São Paulo and Thane, whilst electricity coverage is nearly 100%, this coverage is provided by a combination of formal supply, illegal connections and private autonomous provision (Section 2.3.3). Drawing on research in India, Roy identifies the prevalence of informalised planning regimes, operating in deregulated and ambitious manners (2009: 76). In the context of overlapping formal/regulated and informal/unregulated strategies for service provision, electricity networks in cities of the South often generate further fragmentation by linking social agendas supporting the disadvantaged exclusively with the formalised spaces of the city, in this way, disregarding sectors of the population in greater need who are often living in informal/unregulated conditions (Jaglin, 2008: 1897; see Sections 7.2 and 7.5 in this thesis).

From material to symbolic power: supporting visions and ideals

Energy infrastructures are embroiled in the roll out of specific visions and ideals of the future, signalling the symbolic power of electricity. In the first half of the 20th century electric light came to symbolise the technological 'sublime' of the modern city, a testament to the power of socio-technical progress. Electrification spoke of a technological vision and a bright future to be achieved through urban planning. At home, "the many uses of electricity… 'seemed to ensure a brilliant future for civilisation' (Nye, 1994: 66)" (Graham and Marvin, 2001: 45-46). Year after year new electricity-dependent devices expanded the consumption abilities of lower and middle classes, as they acquired a broad range of gadgets embedded with a "symbolic resonance" (Nye, 1999: 167). The symbolic power of electricity is carried through to the late 20th and early 21st centuries, but with a new set of imaginaries. A new modernity has been rolled out, to be achieved via 'green' and 'clean' technologies. Solar photovoltaic systems, grid-connected wind turbines, and SHW have become the new fuel for the contemporary utopias of modern living (Maassen, 2011). This new 'eco-modernity', brought about by the symbolic power of energy infrastructures, is discussed in more detail in Chapter 5 (Section 5.4).

Mediating between nature and the city

Energy infrastructures function as a form of 'technonature' bringing elements of the natural world into the home, whilst structuring the city and its socio-technical interface with nature (Swyngedouw and Kaika, 2000). They play a key role in structuring what scholars refer to as 'urban material metabolisms' (Monstadt, 2007: 327). Energy infrastructures use, mobilise and transform natural resources and act as an interface between nature and society (Monstadt, 2009: 2). Far from being distinct and clearly separated ontological entities, nature and the city operate in a mesh of "networks and flows of natural elements, social power relations and investment cycles" (Kaika, 2005: 5). Understanding the city as a process of urbanising nature points to how energy infrastructures, rather than separating nature and the city, bring them closer together (Swyngedouw and Kaika, 2000: 567).

Studies on the production of technonatures, whilst primarily focused on water networks (Kaika, 2005; Kooy and Bakker, 2008; Giglioli and Swyngedouw, 2008), have also uncovered the deep physical, social, cultural, economic and political entanglement between water and electricity. The implications for the city are significant because this 'production of nature' occurs through the 'production of scale', as exemplified by Swyngedouw's study on the development of Spain's hydro-social dream and its role in establishing a national high-voltage grid (2007). In Spain, as in Brazil (Chapter 2), hydroelectricity was vital for the modernisation and urbanisation efforts, which rest on a large-scale strategy for building and connecting reservoirs and dams. These energy infrastructures transfer natural resources from one region to another, and were advanced by silencing regionalist impulses and mobilising power through social networks that embrace the interest of national over regional scales. Here "discursive, symbolic and material processes [enrol] H2O in a specific manner" leading to the primacy of certain groups over others (2007: 24).

Thus, who has access to this urbanised nature, and who does not, denotes power relations in the form of resource access and control. An understanding of how energy infrastructures mediate between nature and the city uncovers the urbanisation of nature, not as a technological or engineering problem, but as a socio-political process with implications for the wielding of power and distribution of resources (Gandy, 2004; Kaika and Swyngedouw, 2000). When linked to debates around renewable and sustainable energy, it becomes clear that "questions of socio-environmental sustainability are therefore fundamentally political questions" (Swyngedouw, 2006: 119; see also McFarlane and Rutherford, 2008: 370; Monstadt, 2009). Such political understanding of the city–nature relationship challenges aseptic and technical notions of sustainability, demanding more in-depth social analysis for any sustainability intervention.

Overall, the literature reviewed in answering the question 'how do energy infrastructures configure the urban?' acknowledges the political nature of infrastructure. It also reveals fragmentation and a multiplicity of overlapping systems for service delivery, particularly in the city of the South. The symbolic power of infrastructure supports visions and ideals, whilst their politically charged materiality mediates between nature and the city. The literature reviewed examines the discourses and rationalities involved in the infrastructural configuration of the urban, but provides limited detail on the actual mechanisms at play and their operations.

3.2.2 Electricity and the emerging urban agendas around climate change and sustainability

The second question evaluated in this literature review revolves around the agencies that are enabled or disabled by energy infrastructures, particularly in the context of urban sustainability debates. The question is framed by the emergence of new urban agendas for infrastructure development and transformation in response to perceived risks, challenges and uncertainties associated with climate change, ageing infrastructure, resource constraints and energy security. It has been argued that this reconfiguration of infrastructures – to be achieved largely through urban governance (Bulkeley, 2010) – is largely aimed at securing key resources required for the city's ecological and material reproduction, particularly those needed to maintain and enhance economic growth (Hodson and Marvin, 2009b). Two key themes emerge in answering this question, both of which point towards a problematisation of the interface between resources and the city and a drive towards re-thinking traditional infrastructure models. First, the emergence of climate change as a discourse and governance practice shaping the city's infrastructures and allowing for a multiplicity of public and private actors to engage with urban agendas. Second, a debate around the appropriate scale of intervention and the role of municipalities in this process.

Energy infrastructures and the urban governance of climate change

In responding to the challenges posed by climate change, an emerging and on-going urban low carbon transition is opening up space for the reconfiguration of urban agendas (Bulkeley et al., 2011). Local authorities around the world have joined transnational networks aimed at developing sustainable energy policies at the city level (Bulkeley and Betsill, 2005) and are exploring mechanisms to strengthen environmental action through assuming new roles in local energy management (Guy and Marvin, 2001: 145). This emergence of climate change as a local policy agenda is transforming the city in a multiplicity of ways, changing the infrastructure networks and material fabric of the city as well as its socio-political dimensions and day-to-day activities. Studies of the governance of climate change have tended to overlook the role that such urban infrastructures play in structuring climate change responses (although, for some exceptions, see Bulkeley and Castán-Broto, 2010; Bulkeley and Castán-Broto, 2013; Hodson and Marvin, 2007; Bulkeley, 2006; Monstadt, 2007). Yet, as Bulkeley et al. (2010) demonstrate, urban infrastructures are not just an inanimate backdrop for action, but rather function as a key catalyst for environmental action as well as the critical means through which the governing of climate change takes place.

The roll out of renewable and decentralised energy technologies is at the forefront of this process. In 'a survey of urban climate change experiments in 100 cities', Castán-Broto and Bulkeley identify the extent to which cities are transforming urban infrastructures and experimenting with "new ideas and methods in the context of future uncertainties" (2013: 92). Seventy five percent of all projects surveyed within the category of 'built environment' and seventy eight percent within the category of 'urban infrastructure' focused on the reconfiguration of energy systems. The majority of these "seek to intervene in energy consumption processes, although there is a trend towards new systems of energy production and generation" (2013: 99). Cities are implementing low carbon systems and renewable technologies through a mixture of different modes of governance, including "traditional government functions of control and compliance (e.g. planning), providing new forms of service (e.g. energy) and enabling (e.g. partnerships)" (Bulkeley and Schroeder, 2008: 2). They are providing the grounds for the development of 'national exemplars', where local and national priorities converge and the local scale is credited with guiding action at the national level (Hodson and Marvin, 2007: 322).

The role of the city in the sustainable energy transformation

Within this emerging low carbon infrastructure transition, Hodson and Marvin (2010) ask 'can cities shape socio-technical transitions and how would we know if they were?' In answering, they critique the popular approach developed by scholars of socio-technical transitions and the multi-level perspective (MLP) for limiting their understanding of the city to a container or 'seedbed' where key actors are located (Hodson and Marvin, 2010). The MLP, which distinguishes between dominant technological regimes operating as stable configurations, emerging niches where innovation is developed and landscapes which provide socio-political and economic context (Elzen et al., 2004; Geels, 2004), has been widely applied to the transformation of energy infrastructures (Späth and Rohracher, 2010; Correljè and Verbong, 2004; Kern and Smith, 2008; Foxon et al., 2010; Verbong and Geels, 2010). When examining the role of the city, the MLP argues that transitions start in cities and from there become national (Geels, 2010: 26). Yet, in this approach, the city's involvement in the transformation of energy infrastructures is seen primarily from the perspective of the local planning system and permit procedures, restricting local agency and overlooking the complexity of scalar relationships.

Offering a contrasting account, Hodson and Marvin (2010: 481) conclude that "agency at the level of the city cannot be reduced to understanding the variety and coalitions of actors (e.g. local authorities, mayors, universities, local economic actors, etc.) attributed to work at this scale". Rather, it is necessary to question the relationship between national and urban scales, in order "to conceive of cities not merely as sites for receiving transition initiatives but also potentially as contexts for more purposive" infrastructure transformations (Hodson and Marvin, 2010: 481). This is important for recognising the power relationships between actors across scales and the production of new state spaces associated with the reconfiguration of energy infrastructures. The multi-stakeholder governance arrangements at play imply the co-existence of various – often conflicting – future visions of the city in relation to energy technologies (Bulkeley and Schroeder, 2008). Thus, as this thesis illustrates through the cases of Thane and São Paulo (Section 5.3.3), understanding the role of the city in energy transitions requires a multi-scalar and multi-stakeholder approach, accounting for the way in which various interests and dynamics located at local, regional, national and international levels play out in the city (Hodson and Marvin, 2009a). It also requires taking into account the role and influence of a broad range of non-state actors, including privatised energy utilities and other competitive energy organisations in charge of structuring supply (Guy and Marvin, 2001: 156-157). This is of particular relevance given the widespread deregulation of utilities and the limited control that cities have over these privatised infrastructures (Section 2.3.2) (Hodson and Marvin, 2010; Monstadt, 2007).

Revisiting the sustainability of 'small-scale' and 'decentralised' technologies

In a context where 'small-scale' and 'decentralised' technologies are seen as promising pathways for responding to the emerging urban challenges of security, climate change and sustainability, 'the local' is often uncritically viewed as the privileged site for environmental solutions (Marvin and Guy, 1997; Lawhon and Patel, forthcoming). Yet, understanding energy networks in the post-networked city (see Section 3.2.3 below) calls for a more detailed analysis of their scalar, social, political and metabolic implications. This involves avoiding simplistic views that a priori deem decentralised energy technologies as more sustainable and prematurely close a debate on their effects (Coutard and Rutherford, 2010: 723).

Overall, the literature reviewed in examining the agencies that operate at the interface between urban energy infrastructures and sustainability debates points to the significant role that urban infrastructures play in addressing climate change. It also highlights the active role of the city in driving and structuring such interventions, and the relevance of considering shifting powers across scale in the advancement of sustainability agendas. The materiality of energy systems in the city appears as a key domain shaping the realm of the possible and structuring its politics.

3.2.3 User interfaces and the re-imagination of urban infrastructures

The third and final question examined in this literature review asks how certain forms of user interface foster specific understandings of the city and its infrastructure. Whilst traditional approaches to (formal) electricity infrastructures see users as the passive receivers of a service, a greater use of decentralised renewable technologies opens up possibilities for the user to become an active player in the "'co-management' of demand *between* consumers and providers" (van Vliet et al., 2005: 3, original emphasis). Here users of electricity are no longer “anonymous captive users”, but rather a new type of ‘energy subject’ (van Vliet, 2004: 79). Their involvement in the energy regime evolves from one of a consumer who chooses electricity providers from a range of market options, to a ‘citizen-consumer’ acting upon the broader ethical and societal implications of their consumption, and a ‘co-provider’ generating part of the energy within their premises (van Vliet, 2004). Such variety of user roles reaffirm how “institutions and infrastructures actively create and structure contemporary patterns of demand” (van Vliet et al., 2005: 6), and open possibilities for re-imagining urban infrastructures in a different way. The answers to this third question are primarily empirical rather than conceptual in nature; yet acknowledging these changes has conceptual implications, as illustrated by Coutard and Rutherford (2011) below.

Post-networked urbanism: decentralised energy technologies and the implications of producing energy in the city

The changing role of users due to a broader adoption of decentralised technologies implies reconfigured mechanisms around infrastructure governance and a different set of relations between municipal authorities and citizens (Coutard and Rutherford, 2011: 120). It also implies the scaling down of systems of provision, “from national to regional, from regional to community, from community to individualised systems” (Coutard and Rutherford, 2011: 118). Together, these changes point to a ‘post-network city’, in which the progressive decline of large centralised infrastructure – and its critique – is associated with the rise of more fragmented technological systems (Coutard and Rutherford, 2011).

The post-networked city juxtaposes an urbanism that relies on large technical networks (centralised, large scale, linear metabolism; see Hughes, 1983) with one that is made of sustainable techno-ecocycles (decentralised, dispersed, circular metabolism), where the user has the potential to play a greater role in the configuration of urban infrastructures. From an energy perspective, Coutard and Rutherford propose four forms of post-networked urbanism, each with different implications regarding user engagement. First, off-grid processes, where traditional centralised networks are bypassed in order to develop services on a local level. Second, circular metabolisms, where users enact local autonomy by creating new forms of linking based on collective local scale decisions. Third, collective infrastructures beyond the network, applicable to areas where the network has not been extended and decentralised technologies are used as a solution. Finally, feed-in to grid, referring to initiatives that foster local generation for the purpose of serving the broader network, such as feed-in tariffs (Coutard and Rutherford, 2011). SHW, the technology that this thesis focuses on, sits within off-grid processes. However, by purposefully generating electricity savings that contribute to grid regulation, SHW also acts as a form of feed-in to grid process.

3.2.4 Strengths and limitations of urban geography's approach to infrastructure

The debates around energy infrastructures reviewed above provide useful tools for the analysis of the current energy transformation of Thane and São Paulo, and are used throughout the empirical analysis (Chapters 5 to 7). Overall, six themes emerge from the discussion. First, the recognition of the politics of urban infrastructure (Graham and Marvin, 2001; McFarlane and Rutherford, 2008) and the acknowledgement of fragmented urban fabrics and overlapping modes of service provision (Coutard, 2008; Bakker, 2003) provide a starting point for a more in-depth evaluation of the social and political implications of the transformation of energy infrastructures. Second and third, the appreciation of the symbolic power of infrastructures in constructing utopian visions of the future (Graham and Marvin, 2001; Nye, 1999) and the recognition of their role in mediating between nature and the city (Monstadt, 2009; Kaika and Swyngedouw, 2000) illustrate the far-reaching extent of the material and political implications associated with a change in energy technologies. Whilst their symbolic power shows how energy infrastructures can be mobilised for a variety of purposes above and beyond resource provision, the mediation between city and nature points to the inevitable construction of scale involved in the formulation of an energy regime. Fourth and fifth, the analysis of the ways in which urban infrastructures are being reconfigured in response to climate change and sustainability discourses (Bulkeley et al., 2010; Hodson and Marvin, 2009b), and the examination of the role that municipal authorities and other urban stakeholders play in this process (Hodson and Marvin, 2010; Guy and Marvin, 2001), introduces the multiple human and material agencies involved in the transformation, establishing the realm of the possible, both in terms of action and contradiction. Finally, the acknowledgement of a multiplicity of roles for the user in the context of solar technologies (van Vliet, 2004: 79) opens possibilities for different interpretations of the user-infrastructure interface in the makeup of urban infrastructure. Such possibilities are linked to a post-networked way of thinking about the city, where the sustainability of decentralised renewable technologies is not to be taken for granted (Coutard and Rutherford, 2011).

Yet the literature reviewed holds three limitations in its understanding of the interface between energy, the city and the agencies involved in the transformation of urban infrastructures. First, in the context of urban configurations resulting from electricity infrastructures, the perspectives reviewed provide limited detail about the workings of the *mechanisms at play* in the transformation of energy regimes and, by extension, of the city. They point to the roles of, for example, privatisation and liberalisation, placing an emphasis on discourse and rationalities. Whilst the social and political nature of infrastructures is acknowledged, along with the manner in which this configures urban territory, the nuanced details involved in the specific social, material and political mechanisms operating in this re-configuration of the urban are overlooked, and further insights could be gained by unpacking the operation of the specific techniques mobilised. How does the way in which the energy problem, as it has been envisioned and resolved, shape and limit the powers endowed to the city and its agents? How do such utopian imaginaries operate in practice and what specific interests are advanced in the process of upholding them? How is energy re-territorialised as socio-technical infrastructures are rescaled? Greater attention to these mechanisms would not only increase transparency in the transformation process but also foreground an understanding of winners and losers.

Second, in the context of the agencies involved in transforming infrastructure, the literature does not always recognise the messy world of infrastructural change, the *multiple contradictions* leading to small and large failures and breakdowns, *and the contingent nature* of the process of transformation (see Barry, 2001: 15). This is not always the case, as, for example, scholars from urban political ecology embrace messiness through an analysis of the 'uncanny nature of the city' (Kaika, 2005; Gandy, 2003). Yet, it is important to stress how, as selected stakeholders embrace new technological arrangements through an explicit 'will to improve' (LI, 2007b), the governing aims do not always become reality; or at least not always in the ways expected. This inherent messiness and contradiction is of particular relevance for cities of the global South, where the formal and the informal operate side by side (Roy, 2005).

Finally, in the context of the user and the subjectivities involved in the makeup of new forms of infrastructure, the user is often seen from primarily a technological perspective. This disregards the ways in which *multiple identities, pre-existing and in formation, shape infrastructure*. The user is not so much a technological piece of the infrastructure, but a contested identity that is formed in the process of transforming the infrastructure, and that re-forms the infrastructure itself through new configurations.

Responding to these limitations requires a set of analytical tools that enable unpacking how energy, in its material and socio-political formations, is thought of, mobilised, and transformed. It also requires a more detailed engagement with the subtle mechanisms by which power and resistance operate on the ground. Finally, it requires an engagement with the emerging energy subjectivities engendered by the transformation process. This thesis seeks to develop such an alternative account of the interface between energy regimes and the city by drawing on Foucault's governmentality and associated literature. An analytics of governmentality provides a valuable conceptual framework for addressing the specific mechanisms at play, where agency is revealed at the interface between human and material agents, their objectives and means, subjectivities and territories. This alternative framework is the subject of the remaining sections of this chapter.

3.3 An analytics of governmentality as a tool for understanding energy infrastructure

The transformation of urban energy infrastructures, for reasons as varied as climate change, resource security or simply the advancement of the agendas of specific stakeholders, inevitably requires significant amounts of governing: conducting the conduct of others towards the achievement of a predetermined set of goals (Foucault, 2009; Li, 2007b). The agents involved in these efforts are not limited to the formal institutions of the state, but include a plethora of other actors, private and public, human and non-human (Li, 2007b). Governing energy infrastructures locally is a complex exercise in power and an attempt at realising authority. It is neither an easy task, nor one that a single agent has the capacity to assume.

This section details the way in which a governmentality framework can be used for understanding the emergence of new forms of energy infrastructure in the city. It introduces different ways of understanding governmentality, and draws on them to propose an analytical framework specific to this thesis. Governing is understood here as the art of achieving the "right disposition of things" (2009: 98). It means "to act on the actions of subjects who retain the capacity to act otherwise" (Li, 2007b: 17). What is governed is not a state, a territory or a political structure, but people, individuals or groups in their relations amongst each other and with the material world (Foucault, 2009: 122; Foucault, 2002: 209). For the purpose of this thesis, what is governed is population in the city in relation to the energy resources and infrastructures that sustain and, in a literal way, empower it.

In a broad sense, governmentality can be understood from three different perspectives (Walters, 2012). First, as a 'genealogy of the modern state' (Foucault, 2009: 354), focusing on the tendency of the Western state to give preeminence to governmental power over other forms of power such as discipline and sovereignty. This usage draws from a historical process where the medieval western state was transformed into a bureaucratic and administrative 'governmentalised' state. Second, as an analysis of a particular form of governing, where the primary focus is liberalism (Rose et al., 2006). Finally, as a broader analytical mode for understanding the exercise of power over the population through an ensemble of "institutions, procedures, analyses and reflections, calculations and tactics" (Foucault, 2009: 108). It is this latter use that informs this thesis.

Governmentality, as an analytical approach, is "concerned with thought as it becomes linked to and is embedded in technical means for the shaping and reshaping of conduct" (Dean, 2010: 27). It deals with the way things are problematised, the forms of truth that are invoked, the legitimising knowledges and the styles of thinking that make a reality amenable to calculation, programming and intervention (Miller and Rose, 2008: 16). In this sense, "to analyse mentalities of government is to analyse thought made practical and technical" (Dean, 2010: 27; see also Legg, 2007b: 10). It also means to unpack the mechanisms by which the objectives of the governed are aligned with those of the governor – and by doing so, revealing how it is possible to govern through freedom (Dean, 2010: 28; Rose, 1999).

It is important to observe that governmentality has been extensively used in the development of a critique of contemporary dominant government rationalities, particularly neoliberal modes of rule (see for example, Barry et al., 1996; Lemke, 2002; Larner, 2000). Its use in this thesis is not directly aimed at critically evaluating neoliberal regimes. In contrast, this thesis draws primarily on Dean's (2010) approach, in line with an understanding of the contemporary "as rather *polytemporal* ...a time combining multiple political techniques and styles of government, not all of which cohere or answer to a single logic of development" (Walters, 2012: 10, original emphasis; see also Dean, 2010: 261-265). However, neoliberalism inevitably acts as a relevant context informing the thesis' use of governmentality, given the role of this political rationality in "actively creat[ing] the conditions within which entrepreneurial and competitive conduct is possible" and establishing techniques that enable "a certain kind of economic freedom [which] might be practised in the form of personal autonomy" (Barry et al., 1996: 10).

3.3.1 Governmental power

Foucault rejects an understanding of power as a system of domination exercised by one group or element over another (Foucault, 1979: 112-113). In contrast, governmental power is not possessed or held, but rather "circulates via networks that work through and produce different bodies, discourses, institutions and practices" (Rutherford, 2007: 296). It is open-ended, hit-and-miss, and lies in the spatial and temporal relationships that agents hold. It does not take solid forms, neither does it live in things. It is not permanent in nature, and should not be confused with resources, such as energy, as these are only the media through with power is exercised (Allen, 2011: 83; 105-107). Rejecting traditional restrictive and prohibitive understandings of power, Foucault defines power in positive ways, where the closing down of possibilities occurs through normalisation and acceptance rather than repression: power "works its ways into people's lives through their acceptance of what it is to be or how they should act within particular contexts and scenarios" (Allen, 2011: 76).

Foucault talks about different modes of power. Whilst sovereign power prohibits and discipline prescribes, government enables. Governmental power operates in the material world: "a power thought of as physical action in the element of nature" (Foucault, 2009: 49). Whilst disciplinary power targets the individual body, governmental power targets the social body: the economy, society and population. Such governmental power is "exerted through various domains that [are] posited as autonomous to the state" (Legg, 2007b: 3). It is aimed at guaranteeing the wellbeing of the population (Foucault, 2009: 11; 37) through apparatuses – or *dispositifs* – of security: the essential mechanisms for responding to the unknown, neutralising risk and providing security for the population. In the context of present material givens and unknown future material conditions (such as flows of water, amount of sunlight, climate variations), population emerges not only as an idea, but as a reality that exists in the foreground of 'inevitable' and 'natural' processes to be nullified, limited, and regulated. With the emergence of such apparatuses of security, government becomes material. Its objective "not so much [about] establishing limits and frontiers, or fixing locations, as, above all and essentially, making possible, guaranteeing and ensuring circulations: the circulation of people, merchandise, and air, etcetera" (Foucault, 2009: 29). Modern energy infrastructures emerge as both an object and a subject of governing, targeting population by providing for their security by ensuring the circulation of goods, food, shelter and lifestyles. In this context, as illustrated by the previous chapter, energy regimes operate as apparatuses of security. They are a key vehicle of governmental power.

3.3.2 Framing regimes of government: the multiple analytics of governmentality

Several authors have expanded on Foucault's analytics of government, proposing a variety of approaches and additional categories for the study of the governing activity. This thesis has been informed by three of these models: Dean (2010) and Legg's (2007b; 2011) approaches to regimes of practices of government, and Li's understanding of assemblage as the way through which governing occurs (2007a; 2007b). All three authors identify several dimensions that need to be examined within an analytics of governmentality. These include episteme, telos, visibility, techne, identities (Dean, 2010; Legg, 2007b), ethos (Legg, 2007b) and a variety of practices of assemblage (Li, 2007a). The three approaches are summarised in Table 3.1.

	Dean (Dean, 2010)	**Legg** (Legg, 2007b; 2011)	**Li** (Li, 2007a; 2007b)
Overall approach	***Regimes of Practices of Government*** Emphasis on the link between power and freedom, where governing works through free agents.	***Regimes of Practices of Government*** Emphasis on the role of resistance in power, acknowledging that power is unstable and reversible.	***Assemblage emphasis*** Assemblages, as contingent and fragile configurations that require constant work are recognised as key sites for agency.

Key dimensions associated with the activity of governing	• ***Episteme:*** ways of thinking and questioning
	• ***Telos***: the utopian element within episteme.
	• ***Visibility:*** ways of seeing and perceiving.
	• ***Techne:*** ways of acting and intervening; mechanisms, technique and technologies.
	• ***Identity formation:*** ways of forming subjects.
		• ***Episteme:*** ways of thinking and questioning.
		• ***Ethos:*** moral form; principles and orientation.
		• ***Visibility:*** ways of seeing and representing reality.
		• ***Techne:*** ways of intervening; strategies and procedures.
		• ***Identities:*** ways of conceiving the people to be governed (statuses, capacities, desires, and shaping of their agency.
			• ***Problematisation:*** identification of deficiencies.
			• ***Six practices of assemblage:***
			  • ***Rendering technical:*** forms and techniques mobilising the required forces.
			  • ***Forging alignments***
			  • ***Authorizing knowledge***
			  • ***Managing failures and contradictions***
			  • ***Anti-politics:*** making political challenges into matters of technique.
			  • ***Reassembling***

Agency framing	• Emphasis on the programmers view.	• Governing occurs through assemblages, involving a re-territorialisation. • Links agency and resistance, highlighting the agency of the subjects of government.	• The 'will to improve' and struggle are in permanent provocation. Governing is always an attempt; an utopian endeavour. • Material agents are party to the assemblage.

Table 3.1: Forms of governmentality informing the thesis' conceptual framework

Regimes of government

In Dean's case and Legg's case, the primary organising category is the regime of government, defined as "relatively organised and systematised ways of doing things", particularly in the context of directing the conduct of the self and others (Dean, 2010: 268). Regimes operate as taken-for-granted ways of exercising government. They are the "routinised and ritualised way we [govern] in certain places at certain times… [and] include, moreover, the different ways in which these institutional practices can be thought, made into objects of knowledge, and made subject to problematisations" (Dean, 2010: 31). Regimes have a purposeful nature and suggest intentionality in the activity of governing. Using the language developed by Li (2007b: 1), they embody a "rationale for improvement" and can also be thought of as a practice of government "in which a concept of improvement becomes technical as it is attached to calculated programmes for its realisation" (Li, 2007b: 12).

Regimes of government are constituted by three elements: governmental rationalities, governmental techniques and subjectivities. The first one, governmental rationalities, are "way[s] of reasoning… calculating and responding to a problem, which is more or less systematic, and which might draw upon formal bodies of knowledge or expertise" (Dean, 2010: 24). They stand in contrast to the second element, governmental techniques, understood as the means, mechanisms, procedures, instruments, tactics and vocabularies that constitute authority and enable rule (Dean, 2010). The use of both rationalities and techniques in governmentality can be traced back to the work of Miller and Rose, who in a seminal work published in 1992 pointed to how "it is through technologies that political rationalities and the programmes of government that articulate them [i.e. regimes] become capable of deployment" (Miller and Rose, 2008: 63). Finally, the third element, subjectivities, refers to the identities imagined and fostered in the process of governing (Legg, 2007b; Dean, 2010). These three elements operate as the key building blocks for an analytics of governmentality; they are discussed in greater detail in Section 3.4.

Whilst Dean's and Legg's frameworks are relatively similar, they differ in their approach to agency and power. Dean's model places greater emphasis on the programmer's view, a concern about the ways in which the objectives of those in a position of governing are carried out through the freedom of the governed. This approach has been criticised for overlooking the individual's agency and portraying rule as a completed project (McKee, 2009; Rutland and Aylett, 2008: 630-633; see Section 3.4.3). In contrast, Legg's emphasis lies in the role of resistance as a prerequisite for the operation of power, thus allowing for a different (and, he would argue, more Foucauldian) entry point for the analysis of governing.

Acknowledging the contingent in the regime: drawing on notions of assemblage

The conceptualisation of governmentality used in this thesis is about how things are made, rationalised and brought into being as problems, always already with the assumption and understanding that this is a contingent process. Regimes of government are not to be thought of as coherent processes on their way to complete and successful execution. On the contrary, regimes are prone to failure, filled with contradictions and subjected to more or less purchase. One of the ways in which scholars of governmentality have tried to think about the 'messiness' involved in the activity of governing is by using the concept of assemblage, particularly relevant for the work of Li (2007a). Li's primary concern is the 'will to improve' (2007b), or the rationale for improvement embedded within governing. Her understanding of governing as a 'will' rather than a fully realised objective recognises an "inevitable gap between what is attempted and what is accomplished" (Li, 2007b: 1). In this context, in contrast to highlighting the resultant formation (as in the case of the regime), the notion of assemblage "flags agency, the hard work required to draw heterogeneous elements together, forge connections between them and sustain these connections in the face of tension” (Li, 2007a: 264). In this thesis, assemblage provides a useful language to emphasise such messiness, and therefore is used in place of regime at different points: it serves for thinking about the complexity and multiplicity of alignments and contradictions through which governing takes place. Whilst assemblage is the way in which the operation of governmentality is conceptualised, the thesis does not intend to put forward an analytical distinction between an assemblage and regime. In fact, the energy regime can only function as an assemblage.

Identifying the dimensions of governmentality

Dean and Legg argue that regimes of government are characterised by a stable correlation between specific dimensions of governmentality: episteme, visibility, telos, techne, identity formation (Dean, 2010) and, in the case of Legg, ethos (2007: 12). Episteme refers to the multiple ways of thinking and questioning the governing activity, thus playing a primary role in the process of problematisation. It stands for the vocabularies and processes used for the production of truth, and the ways in which thought seeks to transform practices (Legg, 2007b: 12). It also refers to the forms “of knowledge that arise from and inform the activity of governing”. Here, thought “has a particular time and place and takes a definite material form” (Dean, 2010: 42). However, despite its apparently rational nature, the thought behind governing is not exempt from explicit value judgements. As the energy problem is defined, and the ‘will to improve’ takes shape, a governmental ethos informs quietly decisions and actions. Such an ethos is the “moral form that distributes tasks in relation to ideas or principles of government [and] the orientation invested in practices” (Legg, 2007b: 12). It informs who benefits and what is valued; for example, the population likely to benefit from an energy intervention or the urban process that is prioritised as a local energy initiative is rolled out.

The governmental dimension of visibility stands for the ways of seeing and perceiving (Dean, 2010: 33) as well as the forms by which reality is represented (Legg, 2007b: 12). It operates through, for example, maps, plans and diagrams. But it can also take other forms by drawing on symbolic imagery. The governing activity also embeds a utopian element, referred to by Dean (2010) as the telos of government. Those aiming to govern not only think that governing itself is indeed possible, "that such government can be effective, that it can achieve its desired ends" (Dean, 2010: 44; see also Li, 2007b: 18), but also aim at creating a 'better' world, community, subject or, for that matter, city. The dimensions of visibility and telos can at times be closely connected, as the symbolic power of images – such as the image of a solar energy system – is often mobilised towards utopian goals.

Two of the governmental dimensions proposed by Dean and Legg, techne and identity formation, play primary constitutive roles in the makeup of two of the elements of a regime: the governmental techniques and the subjectivities. In an abbreviated form, techne refers to the "ways of intervening in reality through strategies and procedures" (Legg, 2007b: 12), whilst identity formation refers to "characteristic ways of forming subjects, selves, persons, actors or agents" (Dean, 2010: 33). They are discussed in further detail in Section 3.4, as part of an examination of the elements of a regime.

Li's take on the analytics of governmentality differs significantly. Bringing together governmentality and assemblage theory, she defines governing as an on-going labour through practices of assemblage: "the continuous work of pulling disparate elements together" (2007a: 264). Power in the assemblage lies in all the agents, or rather, in their ability to mobilise different powers at different times. In an attempt to step away from what she considers governmentality's excessive emphasis on the practice of problematisation, she argues that governing through assemblages involves six other practices: rendering technical, forging alignments, managing failures and contradictions, anti-politics, authorising knowledge and reassembling. The first of these, rendering technical, defined as the act of converting complex 'problematic' relations into formulaic interventions aimed at producing beneficial results, is akin to Dean's (2010) and Legg's (2007) governmental techniques (see also 2008).

Overall, Li's approach to governmentality disentangles the complexity of how the forces at play operate in practice, pointing to the subtle negotiations and translations involved in the governing attempt, where varied objectives are pushed through – via conflict and compromise – by diverse agents. Her framework usefully examines a broad variety of types of agencies at play, expanding the range of governmental procedures involved and explaining these in the specific context of assemblages. Forging alignments is defined as "linking together the objectives of the various parties to an assemblage, both those who aspire to govern conduct and those whose conduct is to be conducted" (Li, 2007a: 265). This governing process inevitably requires managing failures and contradictions, defined as the need to retain control over failure by pointing to possible correctives, achieve compromises when required and resolve contradictions (Li, 2007a). The variety of practices of assemblage devised by Li allow for an understanding of specific governmental techniques such as, for example, quality standards and training programmes (Chapter 6), as forms of anti-politics (depoliticising questions around who is entitled to manufacture legitimate solar products) and ways of authorising knowledge. They can be used to explain how certain objects – such as a solar energy system – undergo a form of reassembling in order to be mobilised towards apparently disconnected aims – in this case non-energy related aims, such as urban growth or social agendas around housing provision (Chapters 5 and 7).

3.3.3 Proposed conceptual framework

The form of governmentality adopted by this thesis (Table 3.2) and the resulting proposed conceptual framework (Figure 3.1) take elements from the three models described above. In using an analytics of governmentality, the thesis embraces the notion of regime of government, yet acknowledges assemblages as the ways in which regimes achieve their means. This points to a notion of incompleteness, a process in formation and the hard work required to 'assemble' different elements in order to reach the governing objective (Li, 2007a: 264; see also Barry, 2001: 10-11). Examining the manner in which governing through assemblages occurs demands an analysis of the workings of governing through the day-to-day activities of everyday lives as well as through the mundane practices of everyday administration (Legg, 2007b). It also requires evaluating the ways in which governing is attempted through freedom, through a process of shaping identities (Dean, 2010; Legg, 2007b).

<table>
<tr><th></th><th colspan="2">Thesis' form of governmentality</th><th>Links to Dean</th><th>Links to Legg</th><th>Links to Li</th></tr>
<tr><td rowspan="3">Key dimensions associated with the activity of governing</td><td rowspan="3">Regimes Of Government: Relatively organised and systematised ways of conducting conduct

… which also operate as…

Assemblages: A process of rule that is contingent and fragile, and that demands constant work towards drawing elements together</td><td><u>RATIONALITIES:</u>

Problematizing energy

Focus on governmental rationalities and multi-sited problematisations

CHAPTER 5</td><td>• Episteme
• Telos
• Visibility</td><td>• Episteme
• Ethos
• Visibility</td><td>• Governing as the attempt to enact a 'will to improve'
• Problemati-sation</td></tr>
<tr><td><u>TECHNIQUES:</u>

Mobilising energy

Focus on governmental techniques

CHAPTER 6</td><td>• Visibility
• Techne (techniques of performance)</td><td>• Visibility
• Techne</td><td>• Practices of assemblage:
• Forging alignments
• Managing failures and contradictions</td></tr>
<tr><td><u>SUBJECTIVITIES:</u>

Developing energy identities

Focus on ways of imagining the subject

CHAPTER 7</td><td>• Identity formation (techniques of agency)</td><td>• Identities</td><td></td></tr>
<tr><td>Agency framing</td><td colspan="2">• Recognition of the role of governmental rationalities and techniques put in place by those conducting conducts.
• Imagining subjects and endowing them with particular forms of agency is part of the governmental effort.</td><td>• Governing is attempted through freedom, through a process of shaping identities.</td><td>• Governing occurs thorough the mundane practices of everyday administration.
• Assemblages as sites of re-territorialisation</td><td>• Assemblages as key sites.
• Material agents are party to the assemblage.</td></tr>
</table>

Table 3.2: Form of governmentality adopted by the thesis

Drawing on the use of governmentality described above, the thesis' conceptual framework seeks to evaluate the emerging 'solar energy regime' resulting from an intentional attempt to transform urban energy infrastructures via SHW systems. It is argued that this transformation is giving rise to a local governance of energy. Like all regimes, the solar energy regime is composed of three elements: first, governmental rationalities (ways of thinking) (Dean, 2010: 42); second, governmental techniques (means, mechanisms, procedures, instruments and tactics) (Dean, 2010: 42); and third, subjectivities (imagined identities) (Legg, 2007b). Each one of these elements is examined in detail through an empirical chapter, focusing on ways of problematising energy locally (governmental rationalities; Chapter 5), ways of mobilising local energy (governmental techniques; Chapter 6), and ways of developing energy identities (subjectivities; Chapter 7). When analysing these elements, the thesis pays particular attention to the role of specific governmental dimensions operating across the regime, namely: episteme, telos, ethos, visibility, techne and identity formation. In addition, two of Li's practices of assemblage, which stand out for their ubiquity in the process of governing solar technologies in Thane and São Paulo, are also evaluated in greater empirical detail: forging alignments and managing failures.

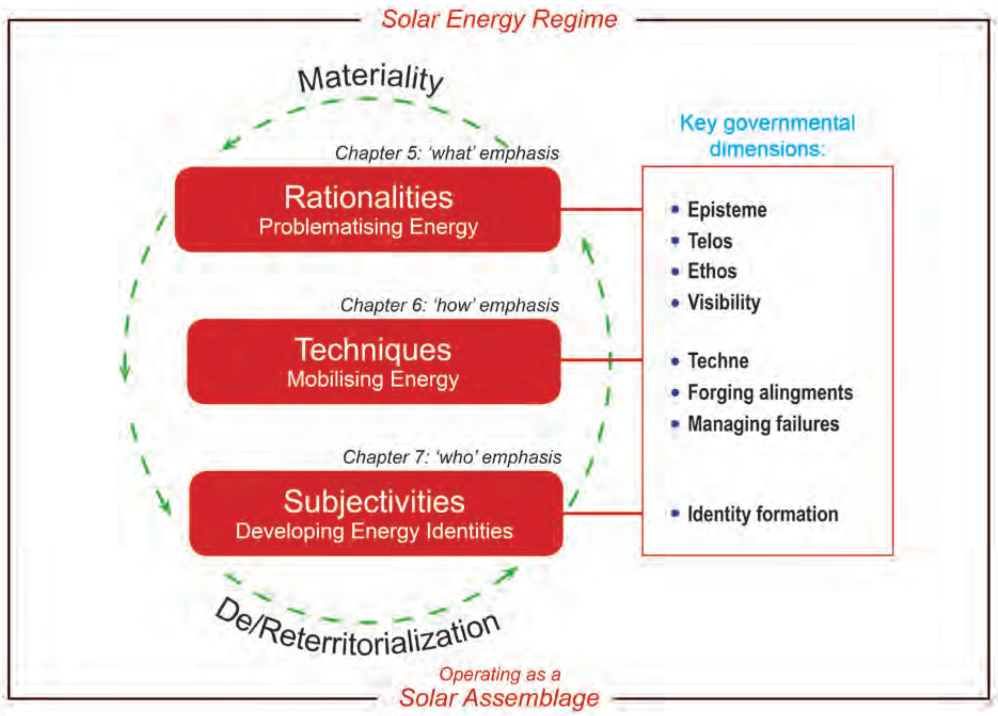

Figure 3.1: Proposed conceptual framework

Drawing on Li's acknowledgment of the contingent in the governing efforts (2007a), the 'solar energy regime' is referred to at times as a 'solar assemblage'. As the key formation by which an emerging form of renewable energy in the city is governed, the solar assemblage can be defined as a contingent, loosely bound and territorially dispersed network of organisations, individuals, objects, materials and natural processes mobilising the energy of the sun via fragile experiments aimed at capturing such energy. As an assemblage, it is characterised by provisionality as well as collective and distributed agencies. It denotes "emergence rather than [a] resultant formation… [along with the] gaps, fissures and fractures that accompany processes of gathering and dispersing" (Anderson and McFarlane, 2011: 125).

Using an analytics of governmentality points directly to how governing the transformation of energy infrastructures in the city "is accomplished through multiple actors and agencies rather than a centralised set of state apparatuses" (Dean, 2010: 37). In locating the nature, origin and location of power within governing, an analytics of governmentality "take[s] apart the self-evidence or truth of governing [… and] de-centres the state as seat of power" (Rutherford, 2007: 294). It uncovers how governing occurs in a multiplicity of locales and sites and how power extends through the social body. Achieving the local governance of energy requires interactions among an extensive assemblage of agents: NGOs and business associations lobbying for particular ideas around energy; regulations and standards framing implementation; and manufacturers, dealers, installers, solar collectors and metering systems participating in the emerging forms of energy circulation. All these agents have their own objectives, operate through particular logics and mechanisms, influence each other and impose resistances. In fact, it is "only because of the work of [such] small figures, with their own aspirations as well as those foisted on them, together with their little instruments, that rule could actually occur" (Miller and Rose, 2008: 6).

The thesis' conceptual framework brings on board two additional dimensions essential to the governing of and through infrastructures: materiality and spatiality. The solar assemblage is made of both human and material agents, in an acknowledgement that infrastructures as well as other material technologies play a primary role in exercising power (Otter, 2007; Joyce, 2003). Assemblage is not the only spatial notion considered over the course of the thesis. Along with it, notions of scale and territory make relevant contributions to the thesis' understanding of the transformation of urban energy infrastructures. Bringing on board the distributedness associated with assemblages implies that the structuring of governmentality is at times scalar: some of the ways in which governmentality operates requires an understanding of the interaction between scales (e.g. local, national, international). At different times, some of these scales become more or less important within the assemblage; thus, scale is important for the form that the regime takes (Bulkeley, 2005; Legg, 2009).[4] Finally, the transformation of energy infrastructures, from centralised to decentralised, also implies changes in territory. This means a transformation of boundaries, circulations and relationships over space (Elden, 2007). This includes a change in the relationship between energy and the user, the dwelling and the city, alongside new spatial meanings associated with this relationship and a re-distribution of responsibilities (e.g. where local stakeholders play a greater role in the energy infrastructure).

The manner in which materiality and spatiality are approached in the proposed conceptual framework is discussed in greater detail in Sections 3.5 and 3.6. The following section (Section 3.4) provides further details on the three elements that constitute the regime: rationalities, techniques, and subjectivities.

[4] Yet, scales do not operate independent of multi-sectorial actors; there are networks cutting across such scales. The notion of networks is also used throughout the thesis. However, its use is primarily descriptive rather than analytical.

3.4 Analytical building blocks: rationalities, techniques and subjectivities

This section describes the three key conceptual building blocks for the empirical analysis of the energy regime: governmental rationalities, governmental techniques, and subjectivities. Energy and electricity, as domains in need of governing (particularly in the context of climate change and resource constraints), are thought of rationally, problematised as an urban issue and addressed at municipal levels through local strategies and stakeholders. Their governing, and the attempt to govern population through them, occurs through a variety of governmental techniques. These include energy masterplans, audits, baselines, targets, contracts, terms of reference and quality standards, alongside practices that attempt to forge alignments and respond to failure. These in turn rely on particular forms of knowledge and expertise, which in turn create specific forms of truth and validate certain energy uses and interventions and not others. Yet the process does not rely exclusively on governmental techniques, because those governing the transformation towards solar infrastructures also seek to construct a new energy subject and endow him/her with specific forms of agency. This subject is guided to be aware of energy issues, to be inclined to adopt solar technologies, to generate his/her own energy, and to reduce consumption. Through this, the subject is guided to align his/her own objectives and ethics to the broader objectives of 'sustainable energy'.

3.4.1 Governmental rationalities: unpacking problematisation

Studies of governmentality seek to understand how a particular domain has been conceived as governable and deemed in need of intervention, how certain sites are constituted as authoritative for this purpose, and how different agents are empowered and assembled towards responding. A key step towards this is the identification of governmental rationalities or mentalities (Miller and

Rose, 2008): the ways of thinking that define what a governmental intervention seeks to change, for what purpose and through which means (Li, 2007b: 61).

An analytics of governmentality interrogates the ways in which things are problematised by examining the moment when the activity of governing is called into question (Dean, 2010: 38; Miller and Rose, 2008: 61). Governmental rationalities stand at the base of the process of problematisation: the expert diagnosis by which the deficiencies to be rectified are identified (Li, 2007b). Problems determine the aims of the practice of governing while giving rise to explicit regimes of government directed at implementing solutions. Rationalities enable problems to emerge in particular locations or sites, formulated through common languages and framed in ways that are amenable to technical solutions (Li, 2007b: 2). This is a complex, slow and selective process, making some problems visible whilst obscuring others, for "[i]ssues and concerns have to be made to appear problematic, often in different ways, in different sites, and by different agents" (Miller and Rose, 2008: 14).

Yet, if governmental rationalities enable the process of conceiving and problematising a domain, thus allowing specific forms of thought to emerge, it is governmental techniques that render these thoughts technical.

3.4.2 Governmental techniques: constituting the domain of intervention

Governmental techniques, associated with the techne dimension of governmentality, are the "ways of intervening in reality through strategies and procedures in relation to the materials and forces to hand and the resistances or oppositions encountered" (Legg, 2007b: 12). Governmental techniques confirm expertise, define an intelligible field of action and roll out specific forms of intervention (Miller and Rose, 2008: 16; Rose, 1999: 33; Li, 2007b: 7). They are composed of "persons, techniques, institutions, instruments for the conducting of conduct" and "devices, tools, techniques, personnel, materials and apparatuses that [enable] authorities to imagine and act upon the conduct of persons individually and collectively" (Miller and Rose, 2008: 16). They are apparently mundane and minor processes, such as techniques of notation, surveying, procedures of examination, systems of data collection and display, and systems of standardisation (Miller and Rose, 2008: 32). Here thought takes material from, as charts, texts, graphs, measuring devices, audits, quality controls and other seemingly mundane devices of the everyday are enlisted in the governing efforts (Dean, 2010).

Dean (2010) gives particular attention to techniques of performance, associated with the development of forms of calculation and measurement. These are characteristic of governmental modes of thinking. Calculative approaches, such as statistics, censuses, or, closer to this research, energy baselines and targets, allow for the identification of risk and danger zones, and thus manufacture the impending crises that stimulate the development of regimes. They are seen to be "simultaneously modest and omniscient", delimiting the field of intervention in present and future times (Miller and Rose, 2008: 212). Calculation makes visible, creating and foregrounding both subjects and objects. By making visible in a numerical way, calculation draws normalisation curves and in doing so defines what is normal and what is not. This numerical knowledge enables prioritisation and opens possibilities for acting, particularly in the hands of the experts holding calculative knowledge.

Nevertheless, the role of techniques of calculation and performance highlight the extent to which governing is not only about representation, but also about intervention (Miller and Rose, 2008: 32). It is precisely through such intervention via mechanisms, procedures, instruments and tactics that rule is accomplished (Dean, 2010: 42). Governmental techniques are not the simple manifestation of governmental rationalities, as they "play an active role in actually constituting the domains that are to be governed" (Murdoch, 2000: 513; Miller and Rose, 2008). They do not only enable power, but also define and limit (by imposing constraints) the realm of the possible (Dean, 2010: 42). For example, techniques prioritise certain roles, actions, groups and individuals, whilst hiding others (Li, 2007b: 234-235). In linking the techne and visibility dimensions of governmentality, the use of governmental techniques reminds us that only that which is made visible exists in the domain of implementation. Only those characteristics that are rendered technical exist in the subjects and objects of government.

However, research on the governmentalities of nature and the environment has focused on a broader range of techniques. These range from the production of reports and discourses on the global monitoring of resources (Luke, 1997; Rutherford, 2007); the use of mapping and other representation techniques for the creation of environmental objects (Demeritt, 2001; Braun, 2000; Li, 2007b); the development of systems and indicators to define, classify and separate objects of environmental concern such as waste (Bulkeley et al., 2007); to the use of scientific knowledge and measuring devices to control the atmosphere (Whitehead, 2011). Governmental techniques are not only discursive and managerial devices, but also as material devices. A definition of governmental techniques emphasising their material qualities is provided by Merriman (2005), who describes them as made up of material and immaterial mechanisms, bodies, technologies and knowledges allowing the conducts of others and the self to be conducted. Thus, "the materialities and distributions of a range of things are integral to the performance of [techniques] of government" (Merriman, 2005: 237).

3.4.3 Subjectivities: agency and the imagined subject

Imagining subjects, and through this endowing them with specific powers, is of relevance for the reconfiguration of energy regimes and the emergence of alternative infrastructure configurations within them. The process of subjectification within governmentality refers to the imperative to develop specific identities (subjectivities) as part of governing. It is akin to the process of identity formation within the dimensions of governmentality. Scaling up solar energy in the city involves fostering solar subjects: creating a renewed set of environmental identities where active subjects are willing to adopt solar technologies by installing and interacting with solar systems in their dwellings. The local governance of energy suggests the emergence of resource-bound identities, alongside a desired set of literacies, and imagined rights and duties within the domain of energy. This includes notions akin to an 'energy citizenship' (see for example Devine-Wright, 2007), and the need for citizens to "have a certain knowledge of [energy] technology, and to make choices on the basis of this knowledge" (Barry, 2001: 29). Such transformation of identities and modes of citizenship targets "the epistemological conception of the people to be governed, their status and capacities, the shaping of agency and direction of desire" (Legg, 2007b: 12).

Subject formation: governing through autonomous actors

Governmental power seeks to engage with the subjects of government "as active and free citizens, as informed and responsible consumers, as members of self-managing communities and organisations, as actors in democratising social movements, and as agents capable of taking control of [their] own risks" (Dean, 2010: 196; see also Blakeley, 2010). Governing occurs "without governing society, [but] through regulated choices made by discrete and autonomous actors" (Rose, 1996: 328; original emphasis). Power here operates positively, not by restricting freedoms but by "enabling certain sorts of action by subjects" (Barnett et al., 2008: 626; see also Foucault, 1997: 225; Foucault, 2002: 326; Rutherford, 2007: 299). This productive (rather than repressing) subject formation entails that "individuals are the vehicles of power, not its points of application" (Barnett et al., 2008: 628).

The discussion around subjectivity within governmentality ranges from the production of entrepreneurial subjects and the redefinition of freedom as capacity for self-realisation (Rankin, 2001: 29; Miller and Rose, 2008: 48; Blakeley, 2010) to the rise of the calculative subject and the emergence of new forms of citizenship (Rose, 1999; Barnett et al., 2008). Subject formation is undertaken not only by the state, but also by a multiplicity of other actors (Rose, 1999: 145 & 164; Barnett et al., 2008: 626). Dean refers to this configuration of identities as a technique of citizenship: "a strategy or technique for the transformation of subjectivity from powerlessness to active citizenship" (Dean, 2010: 83). Here citizenship and freedom come together, as citizenship is manifested "not through entitlement but through the 'free' exercise of individual choice" (Rankin, 2001: 29; see also Rose, 1999: 152; Leffers and Ballamingie, 2013: 137). Such emerging forms of citizenship are based on governmental techniques that promote empowerment, public participation, consultation and negotiation. In this way, the solar regime operates through transforming subjects via environmental awareness programmes and public information centres (Chapter 6), and the conceptualisation of novel rights and duties in relation to energy (Dean, 2010), such as the right to knowledge about solar energy and the duty to care for the environment through the use of specific energy forms (Chapter 7).

Locating agency within governmentality and testing its limitations

Debates around the governmental construction of subjectivities point to a longstanding debate in the social sciences that juxtaposes agency vs. structure.[5] Drawing on a relational understanding of power, where power is not held but circulates, governmentality both criticises and transcends the agency-structure dichotomy. This is achieved via two mechanisms. First, the recognition of freedom

[5] At the risk of oversimplification, agency refers to the ability of individuals to make choices based on beliefs and values. This reveals an approach grounded on utilitarian modes of thinking (Shove et al., 2012: 2), where individuals make choices based on a rational calculation of 'utility', and with practical policy implications that prioritise mechanisms that emphasise rational choice (e.g. markets, taxes and incentives). In contrast, structure refers to the material, economic and cultural conditions shaping choices and behaviours. Here the possibilities of action of the agent are limited by external conditions outside its control.

as a governing mechanism implies that agency plays a role in as much as governing is a creative activity where those who seek to govern imagine a better world and devise strategies to achieve it (Rose et al., 2006: 99). Yet, this agency is framed by governmental rationalities and techniques, where freedom is not the absence of constraints but an array of invented techniques of the self. If freedom occurs in the context of invented techniques, it is argued that the agency-structure binary is meaningless (Rose et al., 2006). Second, an understanding of resistance as a constitutive element of power points to dissent and contradiction as a space for individual agency (Legg, 2009: 60), thus integrating agency and structure. Resistance is not external to power but located at all points within the network, as power can only operate in relation to such opponents, points of support and targets (Foucault, 1979: 93-96).

Two significant pitfalls are embedded in such an approach to agency. The first one relates to a form of governmentality that is primarily concerned with 'the programmers view' (Dean, 2007: 83; see also Rose et al., 2006), where the dominant representation of power "is omnipresent and totalising: thereby precluding the possibility of meaningful individual freedom and human agency" (McKee, 2009: 474). This is a governmentality that portrays rule as "a completed project, simply applied to a passive populace" (Rutherford, 2007: 292; Dowling, 2010; Rutland and Aylett, 2008). If the locus of power is the state or those in power – with their 'invented techniques' – the governed play a limited role in the creation of such techniques resulting in a conceptually limited engagement with the governed in spite of their freedom, and an understanding of the subject as an identity to be shaped. The second pitfall applies to governmentality in a more general sense, where the emphasis on resistance as an expression of agency fosters a theorisation of 'the social' only "in terms of re-active behaviour… *only ever recognizable as resistance*", removing the possibility of positive and productive engagements where socio-cultural change emerges from the subject (Barnett et al., 2008: 628, original emphasis).

This debate, when applied to the transformation of energy regimes, reveals how governmentality lacks meaningful points of connection with the final energy user other than those provided by the act of imagining subjects and shaping their identities, or by the resistance these might offer. Yet subjects can engage with energy infrastructures in a multiplicity of other, for example, more proactive ways. However, a different set of (non-governmental) analytical tools would be better suited for such an in-depth engagement with the final energy user, an aim which is not the central concern of this PhD thesis. Notwithstanding such arguments, it is important to recognise that agency does not lie exclusively with those who hold the will to improve, nor in the subjects they imagine or those who resist. Indeed, it lies also in the multiple material dimensions that makeup the assemblage, from the sun and its sunlight to the material technologies that convert it into energy.

3.5 Governing material technologies

From its very foundations, an analytics of governmentality acknowledges the material dimensions associated with the exercise of power (Section 3.3.1). The transformation of urban energy infrastructures occurs through governing mechanisms operating through, and in tandem with, natural processes and material technologies. SHW technologies, alongside the pre-existing material conditions of the city (in the form of electricity networks, housing typologies and water distribution systems), play a fundamental role in shaping the realm of the possible, the scope of the intervention and its possibilities for success and failure (Lovell et al., 2009: 94; Bulkeley, 2010; Rutland and Aylett, 2008: 38). The materialilty of technology "is generative not merely in the sense of bringing new things into the world but in the sense of bringing forth new worlds, of engaging in an ongoing reconfiguring of the world" (Barad, 2007). It has been argued that, within social and political analysis, an examination of the "apparently more mundane technical objects and practices", such as those involved in energy generation, deserves greater attention. "To analyse the conduct of political and economic life without considering the importance of material and immaterial devices and artefacts is simply to miss half the picture" (Barry, 2001: 10). A deeper understanding of the material dimensions of the urban energy transformation and the emerging solar energy regime sheds new light into the research problem, signalling how technologies and their materiality frame the relationship between governing efforts and their possible realisation (Lovell, 2007), as well as the multiple resistances and their reinterpretation.

In a world that operates through combined human and material agencies (Latour, 2005), power "is recursively woven into the intricate dance that unites the social and the technical" (Law, 1991: 18). The arrival of solar technologies as a form of energy in the city disrupts established power relations long embedded in other forms of infrastructure. The process of transforming infrastructure is a process of old powers resisting and new powers coming into play. Recognising this within the governing effort means acknowledging the materiality of infrastructure as a vibrant force that shapes the governing efforts (Bennett, 2005; Rutland and Aylett, 2008). The importance of the material is not necessarily its physicality, but its role in retaining the links, performing reality, and thus, maintaining the sum of the interactions (Law, 1999: 6). The relationships held together by energy technologies makeup the infrastructure, both in its social and its material dimensions. Transforming energy means transforming such relations. In this transformation scenario, what was taken for granted cannot be taken for granted anymore. Systems, regulations, machines, behaviours, and overall the relations of the socio-technical networks of infrastructure are reconfigured, requiring their material, political and social dimensions to be un-black boxed, re-deployed and re-enacted. The new order settling into place reveals issues of power and domination, and enables new players as well as new forms of governing to emerge, underpinned by new governmental rationalities and technologies.

3.5.1 Liberal infrastructures: governing through technology

Drawing on governmentality frameworks, Otter (2007) and Joyce (2003) have explored the relationship between governing, technological machines and the city. Otter criticises traditional takes on governmentality (e.g. Dean, 2010; Miller and Rose, 2008) for focusing on bureaucratic and discursive governmental techniques, silencing "the brute materiality of technology" (Otter, 2007: 578). Writing in the context of liberal governmentalities, Otter suggests that the material dimensions of government are better captured by the notion 'the government of technology', where technological systems are endowed with an agency of their own and play a key role in allowing liberal subjects to be conducted by shaping how they conduct their own conduct (Otter, 2007).

When considered relationally alongside ideas and practices, the materiality of technological systems carries a political significance. Within the space of liberalism – a form of governmentality which alongside rights and liberties "uses the capacities of free subjects as [means for] achieving its purposes and goals" (Dean, 2010: 267) – "liberal government was not just the government of technology… It was also government through and by technology" (Otter, 2007: 578, original emphasis). Here, multiple machines and socio-technical networks – from roads and sewers to electricity grids and gas networks – secure in a dispersed way particular forms of human agency, operating as a way of materialising an indirect mode of rule. In the city, material infrastructures operate as techno-social solutions of a political nature. Such politics is enhanced precisely by the fact that the solution is implemented as 'technical', therefore external to political domains (Joyce, 2003: 7). Infrastructure networks – and energy regimes – operate as an essential and inherently liberal strategy for the achievement and provision of security, achieved through and by their materiality. In transforming them, and in resisting such transformation, energy territories are re-drawn and scales are reconfigured.

3.6 Territories: redefining the spaces involved in making energy

Drawing on Deleuze, Legg points to how an assemblage is in itself a process of de- and re-territorialisation (Legg, 2009: 238-239).[6] The transformation of energy regimes, via the solar assemblage, reterritorialises energy: it changes the way in which relationships occur in space. Energy generation is no longer centralised but it occurs at a local level, through a variety of locally dispersed stakeholders that start playing a greater role in the makeup of energy infrastructure and through redistribution of the responsibilities associated with energy. In this way, energy regimes, and their transformation, configure both territory and scales (Brenner, 2001; Legg, 2009; Bulkeley, 2005: 897). With the rise of the local governance of energy, the constitution and management of energy networks traditionally occurring at central (national or macro-regional) levels acquires an urban dimension. New and local agents become an integral part of the roll out of strategies aimed at replacing and balancing the loads of distantly generated electricity (see Chapters 2 and 5). Energy is generated locally through an informal network of manufacturers, dealers and installers of decentralised renewable technologies, and the user becomes a key component in the management and regulation of the electricity grid (see Chapters 5 and 7).

The distributed agency associated with making energy locally re-territorialises energy in manifold ways. That is, it redefines subjects and boundaries, re-establishes circulations, and recodifies spatial meanings. Such re-territorialisation produces spatial as well as social changes, and some of these are

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[6] Legg criticises the notion of assemblage developed by Li (2007a) for ignoring the distinction between assemblage and apparatus and failing to differentiate between processes of de- and re-territorialisation (Legg, 2011: 131). In his view, apparatuses are "the re-terriorialising forces within assemblages, that is… the normalising and governmentalising elements of networks" (Legg, 2009: 239). Drawing on the similarities and tensions established by the notions of assemblage and regime of government (Section 3.3.2), this thesis does not emphasise the distinction between assemblages and apparatuses established by Legg.

scalar in nature. Scale here refers to the spatial interactions that are part of that re-territorialisation and that at the same time involve different levels of governing (from the individual and the dwelling to local, national and international levels).

3.6.1 Understandings of territory within an analytics of governmentality

Governmentality's decentring of the central state as the primary and natural node of power opens possibilities for critically unpacking notions of the state, the city and other territorial scales. In embracing an understanding of power beyond the state, governmentality enables an analysis of how the practice of governing occurs in alternative sites and how such sites become authorised (e.g. the city in its task of generating energy; Chapter 5) (Rutherford, 2007: 303). While governmentality is intended to focus on population rather than territory, it retains an important spatial dimension given its object-subject composed of 'men and things'. In this sense, governmentality is 'deeply geographical' and stands in contrast to sovereignty which could be seen as being more geopolitical (Crampton and Elden, 2007: 7-9).

Elden (2007) points to an understanding of territory beyond a configuration of land across space. Rather, territory is "a rendering of the emergent concept of 'space' as a political category" (Elden, 2007: 578). If territory is political, re-territorialisations inevitably point to shifting powers. Foucault's concern with territory is not in relation to the sovereign bounded spaces where states or governments operate (e.g. national territories, municipalities or cities) but aimed at the problematic of its qualities and its security (Foucault, 2007: 176). Thus, territory is used in a more expansive way, and seen as heterogeneous, problematised and internally differentiated (Crampton, 2013: 385 - 388). It is seen as vibrant, relational and dynamic; it has qualities, variables and measures (climate, wealth, resources, irrigation, etc.) that are an integral part of political rule (Elden, 2007: 575).

Earlier in this chapter, Section 3.2.1 illustrated how energy infrastructures configure the city in spatial, social and political ways. By shifting sites and practices of production and consumption, the local governance of energy re-territorialises not only the state and its nation-city interface, but also the way in which energy infrastructures relate to a variety of spatial constructions. Neighbourhoods, dwellings, bathrooms, roofs and showers, play a role in the makeup of the local governance of energy. Citing Callon and Latour, Barry (2001: 12) acknowledges the extent to which "the 'macro-political' order of the state is built up from a complex network of localised technical practices and devices". Thus, governing territory is only possible through the spatial interconnectedness of such technical practices, a notion that applies to both centralised and decentralised energy regimes. Yet, a transformation from exclusively centralised towards the inclusion of decentralised modes inevitably reconfigures both territory and the 'macro-political' order.

3.6.2 The constitution of scale via resource circulations

A scalar vocabulary of space is crucial to understanding how governmentality is assembled (Rutherford, 2007: 294). Legg suggests that scales are effects rather than structuring elements, functioning as narrative devices and techniques of governmentality (Legg, 2009: 235). Several other authors have criticised the naturalisation of space and scale, arguing against understanding scales as fixed, bounded and pre-given entities (Bulkeley, 2005: 897). They claim that 'scale is socially constructed' (Marston, 2000) and point to possibilities for uncovering 'the politics of scale' (Smith, 1992; Brenner, 2000; Swyngedouw and Heynen, 2003). Scalar structuration is "continually reworked through everyday social routines and struggles, …dialectically intertwined with other forms of sociospatial structuration …constituting geographies and choreographies of social power" (Brenner, 2001: 605-607).

Revealing the historicity and effects associated with scale construction and operation uncovers the workings of power in the city and the socio-technical networks that operate at various spatial scales within it. A critical governmentality analysis reveals the ways in which power operates across scales, from nations to cities, neighbourhoods and dwellings. "Applying scale to notions of rule means that we can see the ways in which the body, the household, the region, the nation, and the globe are imbricated and mutually constituted by and through the operation of governmentality" (Rutherford, 2007: 304). Scale is both produced through governmental techniques and operates as a governmental technique in its own right, functioning as an 'apparatus of capture' (Legg, 2009: 239). Processes associated with the generation and circulation of energy, particularly the deployment of large-scale centralised generation strategies, play a role in constructing national and regional scales and assign particular powers to such forms of relationship (Chapter 2; Swyngedouw, 2007).

3.7 Conclusions

This chapter started by asking three questions around the manner in which a transformation in energy infrastructures affects broader social, political and governance processes in the city. How do electricity infrastructures configure the urban? What agencies are enabled by them within the context of sustainability debates? And finally, how does the user interface generate specific understandings of the city and its infrastructure? Answering these questions through the body of knowledge developed by urban geography revealed the extent to which infrastructures are political, possess symbolic power, mediate between nature and the city, and are mobilised towards the advancement of sustainability agendas. It revealed how municipal and other urban stakeholders play a key role in such transformation towards greater sustainability, often via a different understanding of the role of the user-infrastructure interface. In the context of ‘post-networked’ ways of thinking about the city, the literature reviewed pointed to the presence of diverse and possibly contradicting notions of sustainability. It also revealed how urban infrastructures have played a role in the generation of spaces of injustice and exclusion in cities in the South.

Despite its valuable contributions, this body of work shows limitations for an in-depth analysis of infrastructure transformation and the makeup of new territories through which energy is governed: it provides little detail about the mechanisms at play, the multiple identities in operation, and the messiness, contradictions and contingencies present within infrastructural development and transformation. In order to account for these aspects, this thesis turns to Foucault’s analytics of governmentality (2009), drawing specifically on the work of Dean (2010), Legg (2007; 2011) and Li (2007a; 2007b). In examining modes of ‘conducting the energy conducts’ of the self and of others, an analytics of governmentality allows for a recognition of the “institutions, procedures, analyses, and reflections, the calculations and tactics” which the exercise of power over the population depends on (and which also form the basis of resistance) (Foucault, 2002: 220). It allows for critical and productive engagements with the different ways in which productive and restrictive notions of power, agency and freedom, operate within urban infrastructures. It facilitates an integrated view that a) uncovers the problematisations underpinning the governing efforts, b) reveals the specific mechanisms at play, c) establishes the role of imagined subjectivities in fostering change, and d) reveals the entanglement between power, scale, territory and the material.

Drawing on Dean (2010) and Legg (2007), the thesis establishes an appreciation of regimes of government, and applies this to the emerging solar energy regime. Such a regime is composed of three elements: governmental rationalities, governmental techniques and subjectivities. An in depth analysis of these elements, through an examination of a variety of dimensions of governmentality – episteme, ethos, telos, visibility, techne and the process of identity formation – unpacks the systematic and organised ways of conducting energy conducts. Drawing on Li's notion of 'assemblages' (2007a), the framework opens possibilities for acknowledging the contingent, incomplete and fragile nature of such a regime. Li's approach also contributes by signalling to the relevance of forging alignments and managing failures, both essential practices of governing. All of the lines of inquiry described above are traversed by two important themes: first, how materialities constitute energy regimes; and second, how the creation of new forms of energy results in spatial transformations (particularly in terms of scale and reterritorialisations). By focusing on the local governance of energy, this framework contributes to understanding what is being governed, how it is being governed and who is being governed. This will be taken up in the context of the empirical data in subsequent chapters. Chapter 5 will focus on the ways of thinking about and problematising energy (governmental rationalities), Chapter 6 on the different ways of mobilising energy in the city (governmental techniques), and Chapter 7 on the varied energy identities fostered in this process (subjectivities).

This thesis' use of an analytics of governmentality is not without limitations. For instance, its ability to engage with the final user and their practices is constrained by its emphasis on the 'programmers view' and the prominence given to the spaces of governing; whether these are centralised nodes of control, state institutions, non-state arrangements or dispersed and fragile assemblages. Incorporating this approach in the conceptual framework has limited its ability to access the user. Also, approaching politics as resistance limits an understanding of positive and proactive alternatives coming from the governed. In an attempt to address these limitations, this thesis focuses explicitly on the agency accorded to imagined subjects when through focusing on processes of subjectification (Chapter 7). An engagement with the direct agency of the subject as user, and its practice of using energy, is an opportunity for further research evolving from the conceptual approach developed in this thesis. These limitations of governmentality and their implications are further discussed in the thesis' conclusions (Chapter 8).

Governmentality provides productive entry points for unpacking the social, political and governance implications of the transformation in energy regimes. Its use in the study of urban infrastructures and the changing electricity regimes of cities contributes to the study of energy by denaturalising the processes and spaces associated with taken-for-granted ways of governing (and transforming) resources. It enables a critical analysis of what Li (2007b) refers to as 'the will to improve' – the calculated programmes for improvement aimed at making the city's electricity networks more sustainable – and the inevitable resistances encountered. This is urgently needed in the context of transformations of energy systems to lower carbon forms.

Chapter 4

Doing research in Thane and São Paulo: Comparative urbanism and traveling ethnographies

4.1 Introduction

This chapter discusses the methodological aspects of the research. This is of particular relevance for two reasons: first, the thesis' comparative nature which draws on difference rather than similarity and, second, its in-depth engagement with material technologies and the socio-technical networks around them, carried out through the mobilisation of ethnographic sensitivities towards the study of a process of infrastructure transformation. The chapter also reflects on the lessons learned throughout the research process, making transparent and highlighting ways in which the process itself (its motivations, sites and methods) influenced the final outcome.

The chapter starts with a discussion around the two approaches which, in combination, make up the methodological strategy used for this research: first, comparative urbanism and, second, an ethnography of a transformation in infrastructure. Comparative urbanism serves as a methodological device for an ethnography of a form of technological transformation across different urban sites. I labelled the resulting approach a 'traveling ethnography of technology', which can be seen as an experiment in both ethnography and urbanism (see McFarlane and Robinson, 2012). This approach contributes towards developing new ways of doing comparative and multi-sited research in the highly local and diverse, yet interconnected, world of environmental urban transformation. It differs from traditional ethnographic methods in its attempt to understand socio-technical dynamics that are highly driven by their material dimensions and that operate through a multiplicity of sites and scales, from the urban to the international. It also expands the boundaries of traditional comparative urban research by comparing – through a methodology that draws on ethnographic sensitivities – one global process common to many localities around the world across two significantly different cities: São Paulo, in Brazil, and Thane, in India. In this way, the chapter also operates as a reflection around the opportunities and difficulties associated with doing a comparative ethnography of urban processes within the short timeframes afforded by a PhD.

The chapter is structured in six sections. Section 4.2 reflects on the comparative nature of the research and introduces both cities, briefly highlighting their differences and similarities. This is followed by Section 4.3 where the research case studies that make up the empirical material of the thesis are introduced. Section 4.4 discusses the notion of 'traveling ethnography of urban technology', and reflects on how the research methodology, far from being an ethnography in the traditional anthropological sense of the word, was informed by ethnographic sensitivities. This is then followed by a discussion of the methods used for data collection (Section 4.5) and analysis (Section 4.6). Finally, Section 4.7 discusses issues of positionality and reflects on the roles of researcher and researched over the course of the research.

4.2 Comparative Urbanism

This thesis is a comparative study of an urban process occurring in two markedly different cities: Greater São Paulo, in Brazil, and Thane, one of the eight urban conurbations that form the Mumbai Metropolitan Region in India. The process compared is the transformation of urban energy infrastructures in the context of climate change and energy constraints, and particularly, the different ways by which solar technologies are being adopted as the solution to seemingly common problems. Both cities are located in the global South, operating in and around the financial and economic engines of two of the world's largest and fastest growing global economies. However, since their population, geographical extension, political context and histories differ, they are configured in significantly different ways. This section introduces similarity and difference in both cities, and sets the context for what is being compared and how this analysis was carried out. In doing this, the section introduces four case studies that provide the empirical material for the thesis.

In undertaking comparative urban research, this thesis does not approach difference as a barrier for comparison. Rather, difference operates as "a tool for creating new conversations and collaborations, for reading different traditions and connections, and for expanding the field of critique and inquiry" (McFarlane, 2010: 730). It is "a productive means for conceptualising contemporary urbanism" (McFarlane and Robinson, 2012: 767). Comparative urbanism, as "a field of inquiry which seeks the 'systematic study of similarity and difference among cities or urban processes' (Nijman, 2007) both through description and explanation" (Lees, 2012: 155), has in recent years experienced a resurgence (Davis and Tajbakhsh, 2005; Nijman, 2007; Robinson, 2005; Ward, 2010; McFarlane and Robinson, 2012). A defining feature of this new comparative urbanism is a desire to step away from pre-existing assumptions of incommensurability, where comparison is not thinkable amongst cities located in different contexts (e.g. North vs. South) (Robinson, 2011; Ward, 2010).

The resulting approach to comparative urbanism generates a type of knowledge that, drawing on notions developed by post-colonial urbanism (Robinson, 2011), does not consider the urban experience of the west as a privileged point of reference, nor the normative path. This creates possibilities for new theorisations emerging from the urban experience of the global South

(McFarlane, 2010) that embrace urban diversity and difference as the guiding principles behind the comparative attempt (Robinson, 2006: 169). The approach has been referred to as 'cosmopolitan urbanism' (Robinson, 2006), given its effort to see all cities as 'ordinary cities', regardless of their condition as wealthy or poor, eastern or western, developed or underdeveloped. Comparing 'ordinary cities' opens up new possibilities for generating knowledge about the urban, "drawn to learn from cities everywhere" (Robinson, 2005: 763) and stepping beyond narrowly defined categories and understandings of the urban experience. Since "imagining better futures for cities depend on having a strong sense of their distinctiveness and creative potential" (Robinson, 2006: 66), a cosmopolitan urbanism acknowledges the capacity of all cities to "shape their own futures" (Robinson, 2006: 170; see also McFarlane, 2010).

4.2.1 Similarity and difference: introducing São Paulo and Thane

São Paulo and Thane, in the Mumbai Metropolitan Region, are in and around the financial hearts of Brazil and India, two BRIC nations seen as the emerging political and economic powerhouses of the global South. Despite their markedly different social, political and urban histories, the urban processes of both cities have a multiplicity of commonalities. By being part of the mega-metropolises of Asia and Latin America, they are at "the leading edge in the combined restructuring of urban scale and functions… [the] leading incubators in the global economy, progenitors of new urban form, process, and identity" (Smith, 2002: 436). Both cities' economies are rapidly growing, and like many other cities in the global South, their resource consumption is growing as the middle class expands, resulting in higher energy consumption and GHG emissions. Yet they face significant challenges in terms of equality and social justice. They are located in countries that are increasingly under pressure to commit to GHG reductions via binding targets (Olmstead and Stavins, 2012), and are actively engaged in the development of climate change responses. However, such climate change responses occur within a context of multiple priorities and competing urban agendas around poverty alleviation, economic growth and environmental drivers (Chapter 2).

Developing this comparative study was a challenging and constantly mutating process, where the emphasis lay sometimes on identifying similarities and sometimes looking for differences. The similarities and common contexts described above provide a justification for the selection of Thane and São Paulo as sites for comparison over and above their status as 'ordinary cities'. Macro-regional (South-South) and national (India vs. Brazil) scales were used in the identification of cities for comparison, with the aim of developing a South-South comparison between urban centres in strong and rapidly growing national economies. However, both cities showed marked differences in terms of their population size and territorial extent, administrative and urban configurations, and colonial past, signalling a broad diversity of political and cultural experiences as well as governance structures. As discussed in Chapter 2, the national histories of their electricity infrastructures differ markedly. Electricity in Brazil has been mainly an industrial endeavour whilst in India it has served primarily a rural function. Both cities' contemporary contexts in relation to infrastructure provision also differ: São Paulo's is marked by a strong private involvement in electricity provision, alongside substantial strategies for resource redistribution and the pursuit of social agendas. Thane's is characterised by electricity provision still dominated by public ownership, in the context of a rapid urban growth centered on the middle classes and the urban elite.

São Paulo

With a population of over 20 million and legally defined as the São Paulo Metropolitan Region (SPMR), São Paulo extends over 8,500 km^2 and is composed of 39 municipalities (Figure 4.1). The SPMR includes the cities of São Paulo (the capital of the State of the same name, with a population 11.5 million) and Guarulhos (population 1.25 million). Yet alternative (more loose, fluid and unbounded) understandings of São Paulo see it as 'Greater São Paulo' or the 'Extended Metropolitan Area': a sprawling metropolitan complex around the

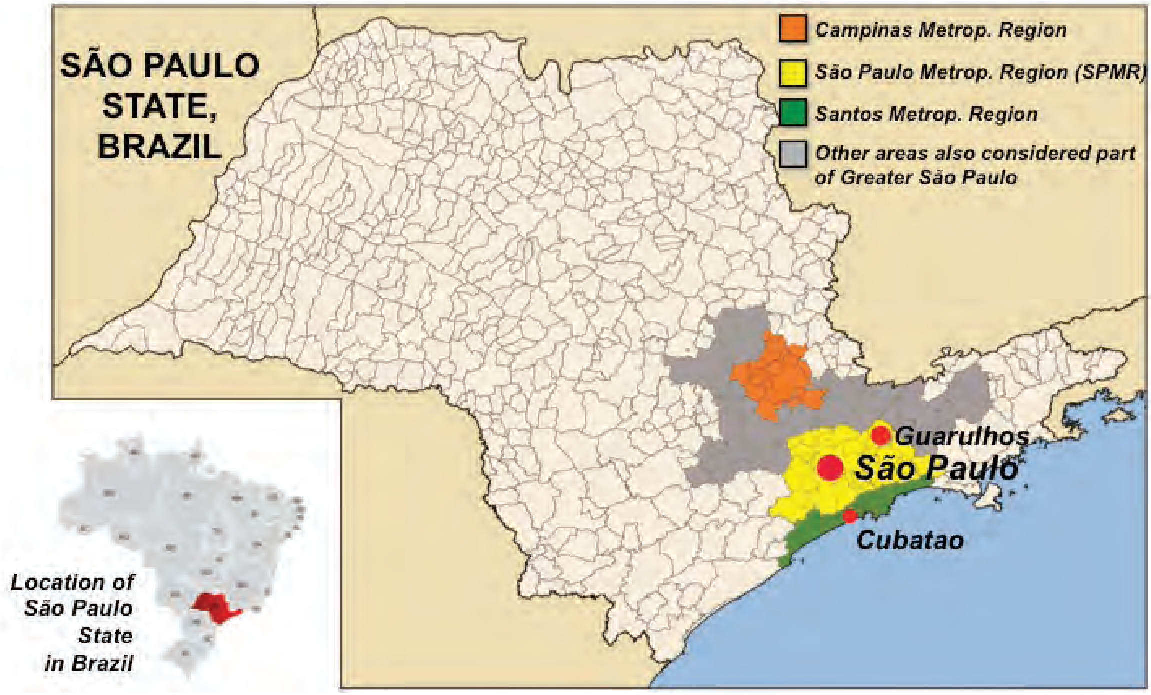


Figure 4.1: Map of the State of São Paulo, Brazil.

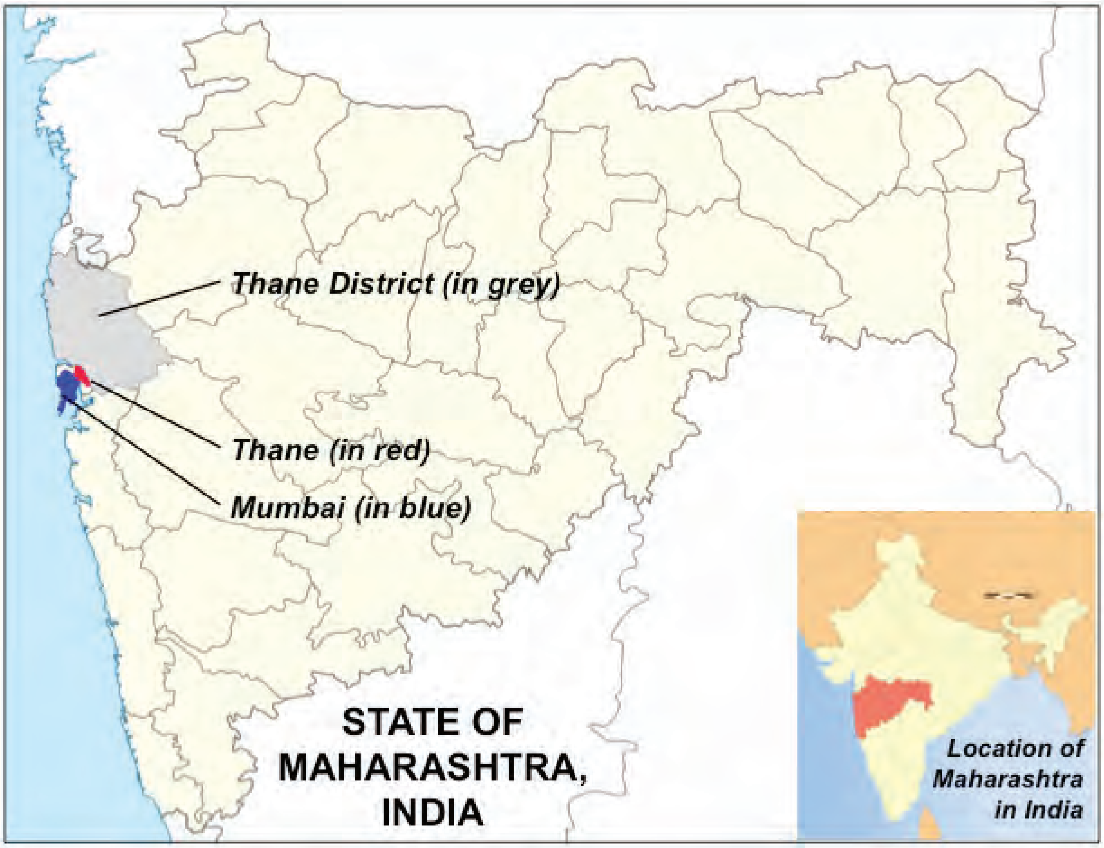
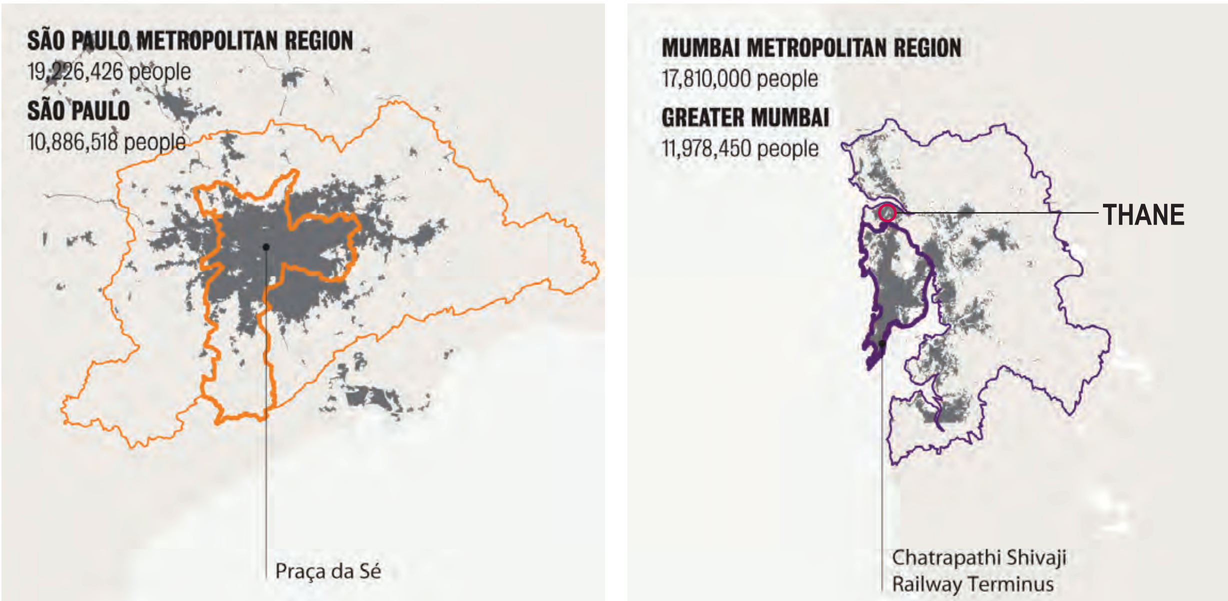


Figure 4.4: Map of the State of Maharashtra, India.

capital, which includes also the adjacent metropolitan regions of Campinas and Santos.[7] There is no unified administrative body for the SPMR, and any attempts at coordinating policies occur through the State of São Paulo. The city of São Paulo (Figure 4.3), like other municipalities across Brazil, functions politically through a mayor and a legislative body elected by the public for a period of four years. The mayor is the head of the executive branch at the local level, which, in the case of São Paulo, presides over 26 municipal departments – or *secretarias* – tasked with the delivery of key services. Whilst municipalities in Brazil are autonomous, there is some limited overlap with the state government for the purpose of service delivery, particularly – for the purpose of this research – in housing provision. São Paulo is Brazil's financial capital and main industrial node. According to PricewaterhouseCoopers, São Paulo has the GDP of all Brazilian cities ans is ranked 10th highest in the world (O Estado de São Paulo, 2009).



Figures 4.2 and 4.3: Map of the São Paulo Metropolitan Region and the city of São Paulo, and of of the Mumbai Metropolitan Region (indicating the location of Thane) (Urban Age, 2008).

[7] In Portuguese, this is the *Complexo Metropolitano Estendido de São Paulo*, which, along with the metropolitan regions of Campinas and Santos, also includes three microregions: Sorocaba, Jundiai and São Jose dos Campos.

Thane

In contrast to São Paulo, Thane is a medium size city by Indian standards with clearly defined administrative boundaries. With an area of 147 km^2 and a population of 1.8 million, Thane is part of the Mumbai Metropolitan Region (Figure 4.4). Located in the Thane District within the State of Maharashtra, it is economically, culturally and historically linked to Mumbai (Figure 4.2). It is a city characterised for its rapid urban growth, and as of 2011 was capturing the majority of population growth within the Mumbai Metropolitan Region. The governing body of the city, the Thane Municipal Corporation (TMC), is headed by a democratically elected mayor working in tandem with an elected legislative body. Like most other local authorities in India, the TMC has only limited autonomy and operates through authority delegated by the state government. The de-facto authority is the city's Municipal Commissioner, a public servant within India's Administrative Service appointed by the governor of the State. During the British colonial period, Thane functioned as a local administrative centre for the British Raj. After India's independence, and particularly in the 1960s and 70s, Thane became an industrial town given its strategic location connecting the port of Mumbai with the interior of the country. Its recent history is characterised by a transition from industrial to commercial and residential activities.

4.2.2 Comparing the transformation of electricity infrastructures in two cities

In this thesis what is being compared is not the city itself, but the process of transforming urban energy infrastructures and adopting solar technologies as a local energy solution. This involves comparing an emerging resource paradigm and the implementation of a new energy regime for the city. The thesis' approach to comparative urbanism, thus, is not limited to bound territorial units, but includes a multiplicity of objects, processes, moments and events within the city. Like with other urban processes – e.g. gentrification (Lees, 2012) – we need to ask what the infrastructure transformation means for cities in the global South, "and in doing so assess the usefulness and applicability of the term as a conceptual frame for processes in the global South" (Lees, 2012: 165). The multiplicity of sites involved in the comparison, from the city itself to processes and technological objects, allows for an engagement with the city "as both a place (a site or territory) and as a series of unbounded, relatively disconnected and dispersed, perhaps sprawling and differentiated activities, made in and through many different kinds of networks stretching far beyond the physical extent of the city" (Robinson, 2005: 763).

The process of selecting cities and case studies for comparison

In using a form of comparative urbanism that embraced notions of cosmopolitan urbanism, selecting cities and case studies for research purposes inevitably meant making subjective decisions regarding the similarities preserved and the differences sought after. This process started before the fieldwork phase, as countries and cities were pre-selected as possible sites for research. Whilst this was not a linear process, once in the field it was necessary to identify cities with relatively mature processes for the implementation of solar technologies. This identification and selection was conducted alongside local research partners: the environmental advocacy organisations that hosted and lent their support to the research and which, in many cases, were involved in the specific projects that they were helping to identify. In India, this process was supported by the South Asia office of ICLEI Local Governments for Sustainability, a transnational association of local governments working on urban sustainability topics and highly involved in the promotion of renewable technologies in cities. In Brazil, it was aided by Vitae Civilis, one of the largest Brazilian environmental NGOs also involved in promoting solar technologies in cities (see Sections 4.5.1 and 4.7.1

for a discussion on the role of the local host organisation over the course of the research).

The final section of cities was determined by three factors: municipal commitment to the use of renewable technologies, variety of solar initiatives and presence of solar industry players. Both Thane and a variety of municipalities within Greater São Paulo (including the city of São Paulo itself) have shown a continued municipal commitment to local energy initiatives, in many cases based on the implementation of projects using solar technologies. This meant that both cities were experimenting with new forms of energy infrastructure, and in doing so, both cities were transforming their energy regime through the involvement of a broad variety of public and private stakeholders. Both cities also host industrial players within the solar industry. São Paulo is the home of the Brazilian Association of Manufacturers of Solar Hot Water Systems (DASOL) as well as the leading SHW manufacturing companies in Brazil. Thane, whilst not a manufacturing site for SHW, has a broad variety of small companies dedicated to the distribution of SHW systems. In addition to these criteria, the selection of São Paulo and Thane provides contrasting case studies from two types of cities: the former, a large urban agglomeration operating at the heart of the global financial circuits and the other a mid-size and contained city operating in the immediate periphery of such flows.

Once the cities had been selected and data gathering had started, a variety of case studies were identified and visited as the thesis' primary unit for data collection. Selecting case studies involved focusing the research on those local energy projects that could provide commonalities (e.g. in technology, in actors involved, in mechanisms of operation), contrasts, learning and, just as importantly, access. This selection process did not end until a few months after the fieldwork phase had finished and analysis had started. The criteria for selecting case studies within the selected cities included the specific project's stage of development, presence of possibilities for access to key stakeholders, diversity of stakeholders involved and the project's scale and impact. Several different solar technologies were examined over the course of the research, but in the end all selected case studies relate to the use of SHW for domestic purposes,[8] as a mechanism to maintain similarity and commensurability across technological processes in the city.

The process of selecting cities and case studies illustrates how comparative urbanism is not linear, but rather messy and contingent, where moving goalposts are not detours but inherent parts of the research process (Crang and Cook, 2007). As a research practice, this requires an "open, embedded and relational conceptualisation of cities" (Ward, 2010: 479; see also Massey, 2007).

The solar technologies and initiatives transforming energy regimes

The following projects were pre-selected as possible case studies, and provide an example of the range of initiatives that the cities involved in this study are using to transform their energy regimes. All of them were subject to a preliminary scoping study involving a basic level of data collection, including interviews:[9]

- ***São Paulo's Solar Law:*** local byelaw making the use of SHW mandatory for new construction.
- ***Thane's Solar Law:*** local byelaw making the use of SHW mandatory for new construction.

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[8] SHW is a mature renewable technology for heating water for a variety of industrial and domestic purposes. Its domestic use is primarily aimed at heating water for basic household needs such as bathing, dishwashing, laundry and cooking, via collectors located on the roofs of buildings. SHW uses heat transfer principles and materials to absorb radiant energy from the sun. SHW systems have been widely available since the 1980s.

[9] The narrative of the empirical chapters (Chapters 5, 6 and 7) includes minor references to Nagpur (State of Maharashtra), a city that is also part of India's Solar Cities Programme. At the time of fieldwork the rollout of the Solar Cities Programme in Thane was under development. Two of the thesis' shortlisted case studies were located in Nagpur, and the interaction with this city provided valuable additional viewpoints. Some of the solar interventions that were still in planning stage in Thane were using Nagpur's experience as an example to follow.

- ***São Paulo's solar cities initiative:*** joint initiative between the NGO Vitae Civilis and DASOL aimed at lobbying local authorities for the adoption of local byelaws requiring or facilitating SHW use. This initiative was instrumental in São Paulo's adoption of the solar law.
- ***Thane's Solar Cities Programme:*** local implementation of a renewable energy initiative of India's central government.
- ***Thane's Solar Air Conditioner:*** 1st parabolic solar system used for air conditioning purposes in India, installed by the Municipal Corporation at Thane's main public hospital.
- ***Thane's Municipal Corporation Solar PVs:*** 50 kW photovoltaic system providing back-up energy to the main offices of the Municipal Corporation.
- ***Nagpur's solar law:*** local byelaw making the use of SHW mandatory for new construction
- ***Nagpur Local Renewables Programme:*** joint initiative between the Nagpur Municipal Corporation and ICLEI – Local Governments for Sustainability for the local promotion of renewable technologies. The project includes a Renewable Energy and Energy Efficiency Resource Centre (REEERC) operating as a demonstration and information hub open to the public.
- ***Solar technologies in Social Housing in São Paulo:*** process of implementation of SHW in social housing.
- ***São Paulo's low-cost SHW:*** process of development, promotion and implementation of a do-it-yourself (DIY) solar technology aimed at low-income population.

Six of these were discarded over the course of the data collection and analysis period. The reasons are varied, such as the decision to establish a focus around a single type of solar technology (SHW systems), practical time limitations for gathering enough data about certain case studies over the course of the fieldwork period, and the need to focus the research on a set of discrete and limited number of research objects.

4.3 Introducing the selected case studies

The selected case studies involve a broad diversity of stakeholders and a variety of lead stakeholders, including municipalities, international organisations, state level agencies and non-profit organisations. They also provide contrasting examples of the targeted users and primary aims associated with the use of solar technologies. Solar technologies within the Indian case studies function largely within the context of elites and middle classes. Such a target population was not a choice within the selection process; it reflects the experience of the fieldwork in India, as no such projects in the context of low-income population were identified. In contrast, in Brazil the users targeted include elites, middle classes and also low-income dwellers, and several of the projects examined operate within social logics towards poverty alleviation.

Table 4.1 below provides a summary of the case studies selected. These are developed in a combined manner throughout Chapters 5, 6 and 7.

	City	Research sites	Scope	Lead stakeholder	Other stakeholders
Case study 1: *Municipal solar laws*	Thane / São Paulo	Thane and City of São Paulo.	Local laws making the use of SHW mandatory for all new construction.	Thane Municipal Corporation; Municipality of São Paulo.	Housing developers, SHW manufacturers, distributers and installers, users.
Case study 2: *Thane's Solar Cities Programme*	Thane	Thane	Central government program supporting the development of energy efficiency and renewable energy initiatives at local level.	Thane Municipal Corporation and ICLEI – Local Governments for Sustainability.	Indian Ministry of New and Renewable Energy – MNRE.
Case study 3: *SHW in social housing in São Paulo*	São Paulo	City of São Paulo, City of Guarulhos and Municipality of Cubatao.	Strategy for the use of SHW in formal (state provided) low-income housing.	Housing and Urban Development Company (CDHU) of the State of São Paulo.	DASOL, manufacturers and dealers of SHW, users, energy utility companies.
Case study 4: *São Paulo's DIY SHW*	São Paulo	City of São Paulo, City of Guarulhos and Municipality of Franco da Rocha.	Initiative for the promotion of low-cost DIY SHW.	*Sociedade do Sol* (NGO).	Municipality of Guarulhos, individual members of the *Sociedade do Sol*'s network of volunteers.

Table 4.1: Case studies - summary.

4.3.1 Case study 1: Municipal Solar Laws

An important step in the local governance of energy in Thane (Figure 4.5) and São Paulo (Figure 4.6) has been the creation of local byelaws mandating the use of solar technologies, specifically SHW. Thane's Solar Law was approved in 2004 and São Paulo's in 2008, both within the framework of the city's planning regulations and building codes. They are examples of municipality-led initiatives based on the use of local byelaws to influence the city's energy makeup. On the ground, the primary stakeholders delivering the initiative are business associations involved in the construction sector, alongside small and mid-size solar business – operating on their own and actively distributing and installing SHW across the city.

São Paulo was the first Brazilian municipality to make the use of SHW mandatory, through a modification of the city's Building Code (*Código de Obras e Edificações*). The city's Solar Law (*Lei nº 14.459, de 3 de Julho de 2007*) requires

Figure 4.5: São Paulo, which approved its Solar Law in 2008 (Case study 1).

all new dwellings with four bathrooms or more to install SHW systems to provide for at least 40% of its annual hot water requirements. All other new dwellings are required to make provision for future conversion to SHW. This includes provision of space for the solar equipment, structural strength to carry its weight and the provision of pipes capable of resisting hot water, an uncommon practice in Brazil. The law was modelled after Barcelona's Solar Thermal Ordinance (Provincia de Barcelona, 1999), and promoted by the city's Environment Department through the Municipality's Committee on Climate Change and Eco-economy. The Solar Cities initiative (*Cidades Solares*), a coalition between the environmental non-profit Vitae Civilis and DASOL, played a key role in lobbying for the adoption of the law.

Whilst for UK standards a dwelling with four bathrooms or more might seem excessive, this is not the case in Brazil. The number of bathrooms was selected by the municipality as a simple indicator of socio-economic level, in an attempt to target upscale neighbourhoods in the implementation of SHW systems. The reference to bathrooms in the Solar Law does not specify the presence of showering facilities. In the words of a staff member of the Municipality involved in drafting the Solar Law, it is common for middle class dwellings to have 3 bathrooms: "that means that there is one bathroom for social issues [visitors' bathroom], the bathroom for the [live-in] domestic staff, [and] the bathroom of the suite… that is the pattern of the middle, middle upper classes" (Interview P21).

Figure 4.6: Thane, which approved its Solar Law in 2004 (Case study 1).

In Thane, the city's legislative assembly approved the Solar Law in 2004 as a modification to the city's Development Control Rules and Regulations (Development Control Regulations 1994 - Notification No. TPS 1203/205/CR-142/2004/UD-12/18th June 2004). Like São Paulo, Thane was one of the first Indian cities to enact a building byelaw making the use of SHW systems mandatory for all new construction, including residential and industrial premises as well as hotels, hostels, health and sports facilities. For existing buildings, the law provides a 10% property tax break for owners that voluntarily install SHW systems.

Figure 4.7: Case study 2: main offices of the Thane Municipal Corporation, home of the Thane Solar Cities Programme.

4.3.2 Case study 2: Thane's Solar Cities Programme

Thane was one of the first Indian cities to subscribe to the Solar Cities Programme developed by India's Ministry of New and Renewable Energy (MNRE). Launched in 2009, it aims to promote energy efficiency and renewable energy in over 60 medium size cities. It was largely modelled after the pilot experience of ICLEI promoting renewable energy technologies in Nagpur, Bhubaneswar and Coimbatore (ICLEI, Undated). Whilst the project is under the formal leadership of the Thane Municipal Corporation (Figure 4.7), ICLEI functions as the primary organisation leading its implementation. This case study exemplifies the scalar governance dynamics involved in rolling out solar technologies in the city, where transnational, national and local stakeholders work in tandem towards project visioning and delivery.

The Solar Cities Programme supports cities in becoming a driving force for local energy innovation and investment. Its formal objective is to empower local governments to address energy challenges, and to provide a framework that enables an assessment of each city's energy situation. The programme also aims to build capacity in local governments and raise awareness about renewable technologies. By joining the Solar Cities Programme, Thane received up to Rs. 50 lakhs (US$ 110,000) from the Indian government, to be used towards the development of a local energy baseline, a local energy masterplan, strategies for increasing energy efficiency and renewable energy and promotional activities around renewable technologies.

Figure 4.8: SHW systems on the roof of a residential tower completed in 2011 by the CDHU in central São Paulo (Case study 3).

4.3.3 Case study 3: solar technologies in social housing in São Paulo

Since 1949, São Paulo's Housing and Urban Development Company (CDHU) has been playing a key role in the delivery of social housing in the State (Figure 4.8). The CDHU is a state-owned company attached to the Housing Department of the State of São Paulo. It is also Brazil's largest social housing company and one of the largest in Latin America. The CDHU has been experimenting with SHW since 2005. Since 2009 it has been using SHW for the majority of its dwellings. This case study is an example of solar technology implementation in cities through the leadership of government agencies at the regional level (or, in the case of Brazil, the state level) level. It is important because of its use of solar technologies in the context of broader social agendas, framed by poverty alleviation schemes and aimed towards a low-income population. It is a case study characterised by the formal and coordinated involvement of the solar industry via the active role of DASOL.

Housing is a key problem at both city and state levels. In 2006, the State of São Paulo had a housing deficit of nearly 4 million units (Secretaria da Habitação, Undated), defined both in terms of lack of housing (~1 million) and housing with substandard quality (~3 million). The CDHU functions by commissioning the construction of dwellings following tightly regulated design parameters. It finances ownership of the dwelling through loans and subsidies for low-income groups. While the official scope of the CDHU is to work with population earning an income anywhere between 1 and 10 times the minimum salary defined by the Brazilian government[10] (72% of the State's households), the majority of its housing provision is directed to families earning incomes between 1 and 3 minimum salaries (18% of the State's households). It has built in the order of 30,000 dwellings per year over the past decade (CDHU, 2013). Whilst the geographical remit of the CDHU is the totality of the State, in recent years the company has been targeting its building efforts in São Paulo's three main metropolitan regions (São Paulo, Campinas and Santos), as those are the areas where the housing deficit is largest.

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[10] Brazil's minimum salary, or minimum wage, is in the order of US$300 per month. In broad terms, low-income population refers to those earning between 1 and 3 minimum salaries, whilst those earning between 3 and 10 are considered middle class.

Figure 4.9: low cost DYI SHW in the *favela* Pretoria, Municipality of Franco da Rocha, Greater São Paulo (Case study 4).

4.3.4 Case study 4: low cost SHW in São Paulo

Since the late 1990s a small São Paulo non-profit called *Sociedade do Sol* has been working towards the technological development, promotion and implementation of DIY low-cost SHW (Figure 4.9). Originally devised in a context where SHW was seen as an expensive gadget for the rich, this initiative aims for the development of renewable energy technologies that, in their view, are more in tune with the economic and social realities of Brazil. Materially, the DIY SHW is manufactured with PVC tubes, plaques and joints available in almost any hardware store. In contrast with industrially manufactured SHW systems, assembling a DIY SHW does not require specialised knowledge. The *Sociedade do Sol* aims to capture the potential of SHW for providing cheap energy for the poor and use renewable technologies as an opportunity for generating environmental awareness. Like the previous case study, this exemplifies the use of solar technologies in the context of social agendas. However, partly because of its leadership by a non-profit organisation, the case study provides an alternative account of what energy is for, of how knowledge about solar technologies circulates, and of the role of the user within urban infrastructures.

4.4 A 'Traveling ethnography of urban technologies'

The overall methodological design of the thesis was framed by an effort to trace the life of an infrastructural object: the SHW system. Its multi-sited nature meant that the research methodology operated as a 'traveling ethnography of urban technologies'. This approach builds on ethnographic approaches to infrastructure (Leigh-Star, 1999; Leigh-Star, 2002; Leigh-Star and Bowker, 2006; Hess, 2001) and an understanding of fieldwork and research techniques proposed by Actor-Network Theory (ANT) (Latour, 2005). SHW systems, as the key material object of the research, were followed in their different incarnations: from their conception (in the spaces of advocacy and policy making) as objects endowed with the power to offer a technological solution to an energy problem, to their implementation and use. This involved observing and interviewing stakeholders involved with SHW, tracing the multiple translations occurring as the technology navigates from one step to the next, from agent to agent, and from material to material. Using a methodological approach informed by ethnographic sensitivities, the fieldwork generated an abundant data set and a rich narrative account of a highly material and socio-technical process within urban environments. But, how is it possible to combine the in-depth research demands of the ethnographic work with the traveling nature of comparative urbanism? How to achieve a 'deep and thick' understanding of an urban process whilst being in two cities, over the limited amount of time afforded by a PhD? This section reflects on these questions by discussing the evolving nature of this multi-sited comparative research, recalling the different methodological traditions that informed its development, and describing what it meant to develop the research in practice over the course of the fieldwork period.

4.4.1 The contingent and evolving nature of multi-sited comparative research

As a researcher, I have been trained as an anthropologist. For this reason, I am mindful of using the term ethnography lightly. Over the course of the fieldwork period, my anthropology degree played out in two different ways. On one hand, it gave me a set of tools and a sensibility that greatly enriched the data-gathering period. This ethnographic sensibility was reflected in my selection of local research partners actively involved in promoting solar technologies in Brazil and India (ICLEI and Vitae Civilis); in my decision to base myself at their offices and (to the extent possible) collaborate with them throughout the fieldwork period; in my efforts to spend time with a variety of actors involved in delivering solar technologies on the ground, particularly the dealers of SHW; in my emphasis on visiting the sites of manufacture, implementation and use of SHW, and, once there, observe how the agents involved interact amongst themselves and with the technology; and in my use of fieldwork diaries and photography. On the other hand, this anthropological training gave me an awareness of the extent to which the methodology I used does not equate to 'doing an ethnography' in the traditional anthropological sense. The time spent in each country was limited to 4 months, and over that period of time I had to visit several cities; the sites of research within each city were multiple and dispersed, and, as I write the thesis, my memories of the everyday in Brazil and India are more related to traversing the city by public transport than to interacting with the object of study; the research fieldwork, in practice, was more about developing and maintaining a database of contacts (via telephone calls and mobile phone text messages) that could lead to interviews (in offices, living rooms and occasionally factories), than about dwelling in the observation practices required by an ethnography. As a result, the primary sources of material for this thesis are interviews (Section 4.5.2), required to account for the loss of detail associated with the traveling needs of the research.

Yet, the ethnographic sensibility with which I approached the fieldwork period contributed significantly to the development of the research. I have referred to the resulting combination of methods and sensibilities as a 'traveling ethnography of urban technologies'. It is a form of research that does not claim to embody the purity of classical ethnographic texts (e.g. Evans-Pritchard, 1940; Mead, 1935), but instead see it as a non-linear and flexible process best described as a "contingent construction" (Crang and Cook, 2007: 207). This form of ethnographic study combines a multiplicity of methods (where participatory observation is one amongst many), acknowledges the practical need to vary the emphasis amongst these methods, and readily takes advantage of the unexpected data gathering opportunities that emerge in the field (Crang and Cook, 2007). This made the research methodology into a comparison with the characteristics of ethnography, rather than a comparative ethnography. The resulting methodology stages both the potential and the challenge of combining a comparative approach with an ethnographic sensibility, a question that is likely to become more important given the resurgence of comparative research in urban geography and urban studies discussed in Section 4.2 (McFarlane and Robinson, 2012).

Tracing the life of SHW systems in the city of the global South required, crisscrossing Thane (and sometimes Mumbai), visiting Nagpur and Delhi to see the sites of inspiration and imagination, flying to Bangalore to understand the material origin of the technology (at manufacturing sites), and finally carrying out similar activities in a variety of cities in Greater São Paulo. Such traveling enriched my understanding of the urban processes compared, by allowing me to evaluate how they play out in different sites. This 'traveling ethnography of urban technologies' responds to the multi-sited nature of an ethnographic practice aimed at uncovering the manner in which global processes – such as the transformation of energy regimes – are played out in local domains (Marcus, 1995). Whilst in the past ethnography “privileged relations of dwelling over relations of travel”, traveling ethnographies decentre the fieldwork site as the primary site of ethnographic research and ‘take place’ “in worldly, contingent relations of travel, not in controlled sites of research” (Clifford, 1997: 22 and 68). As described by Marcus (1998: 90), “multi-sited research is designed around chains, paths, threads, conjunctions, or juxtapositions of locations in which the ethnographer establishes some form of literal, physical presence, with an explicit, posited logic of association or connection among sites that in fact defines the argument of the ethnography”. A multi-sited ethnography of urban processes requires constant traveling across the city (visiting sites of visioning, manufacture, delivery, assembly and use) and across cities (tracing how dynamics occurring in one city influence another and how a seemingly similar urban process plays out in different urban contexts). This multi-sited traveling ethnography serves the needs of studying changing resource dynamics in cities, events that “cannot be accounted for ethnographically by remaining focused on a single site of intensive investigation” (Marcus, 1995: 96). It is a rewarding approach as it yields a rich data set and a comprehensive understanding of the materiality-policy-implementation interface.

Yet this methodological approach does not come free of burdens and anxieties. During fieldwork, adopting practices of “moving to and from, in and out, [and] passing through” (Clifford, 1997: 67) imposed an extenuating schedule of activities and travels in, to and from, several cities that I was visiting for the first time, in two new countries. A PhD, like any other research endeavour, has only a limited amount of time available for fieldwork, and working with two cities imposed further constraints for data collection. Time limitations for the fieldwork phase in each city inevitably resulted in methodological anxieties around the ‘attenuation of the power of the fieldwork’ (Marcus, 1995). This required balancing the ethnographic ‘dwelling’ of participatory observation instances (Clifford, 1997) with the copious but sometimes antiseptic and place-detached narrative accounts resulting from interviews.

The ethnography involved three overlapping learning processes: learning about the technology, learning about the city, and finally, learning about the interaction between these two. Upon my first arrival in Thane I knew very little about SHW, but as the comparative fieldwork moved forward my knowledge about the technology increase vastly. When the research site changed from Thane to São Paulo, the research experience drew upon this previously acquired knowledge. In practice, this resulted in fewer project visits in São Paulo, with those project visits that were undertaken more focused around the evolving key themes, in this case the interaction between the technology and social agendas. Urban comparison changes the way in which the researcher thinks about the life history of infrastructure; like peeling an onion, it also allows for a greater and more in depth understanding of how the material is entangled with the social.

4.4.2 Drawing on the methodological principles established by ANT

The methodological approach drew from ways of doing research developed by ANT scholars. By closely following the agents (whether human or non-human) and describing in detail the relationships amongst them, this approach offered productive opportunities for engaging with the integration of social and technological domains (Law, 1991). In the context of the study of infrastructure transformation in cities, this suggests the importance of providing greater attention to the material dimensions of such processes. It challenges us to think about the agency of these material elements, and the possibility of them having a voice: energy itself, electricity, water, solar collectors, water tanks, showers and pipes (Section 3.5.2).

ANT highlights the multiple ways in which things can happen, not only through the domain of policy interventions or technological experimentation, but through a host of other domains and relations. In ANT 'the social' is traced through material means, "follow[ing] the actors in their weaving through things" (Latour, 2005: 68-69) and their "*summing up* [...] interaction through various kinds of devices, inscriptions, forms and formulae, into a very local, very practical, very tiny locus" (Latour, 1999: 17, original emphasis). A methodological understanding of materiality and relationally is achieved by 'latching on' and following SHW systems, by looking at the things that 'stick' to them and the 'translations' at place, as they move from vision and imagination to material presence and practice. These translations occur as the manufacturers manufacture SHW systems, dealers deal with them, prospective users buy them, and installers install them. They also occur as water circulates through them, through water meters, plastic and copper pipes, and as the solar rays intended to fall upon them are blocked by the clouds; and as housing and water infrastructures join this energy infrastructure into new building typologies, made of more or less renewable energy forms.

4.4.3 Tracing the life of infrastructure in practice

Following technology as a research practice meant an exhausting schedule of meetings, interviews, site visits, travels and journeys. Occasionally it would involve accompanying a dealer in his quest for new clients, or as he visited an old one to collect a cheque, or attending practitioner conferences organised by the SHW industry. It would also involve climbing onto roofs and, there and then, asking about pipes and joints, broken glass and bits of plastic lying around. And, when interviewing users, asking whether they would mind showing me the bathroom and pointing to where the solar hot water actually comes out. There was never any apprehension on the side of the interviewee at the thought of continuing the interview in the bathroom; on the contrary, my request would be welcomed with excitement, as the user – and often owner of a SHW system – proudly explained the arrangement of water faucets and opened the tap in the hope that, despite a cloudy day, hot water available would still be available. Then, as hot water came out, a look of satisfaction would follow; a sense that they knew a trick no-one else knows. These conversations in bathrooms, despite not making it into the final written thesis, were always revealing, like when a young user explained how easy it was to get solar hot water only by flicking a switch. Ironically, the switch happened to be connected to the electric boiler.

Tracing the life-history of SHW systems, and identifying the multiple translations involved in their constitution, enabled drawing an account of how such sociotechnical intervention came into being; with what meanings, forms and mechanisms. It involved following the different elements involved in the makeup of SHW (the practices, material technologies and users). Fieldwork occurred at many sites and took different shapes, following commodity chains, examining manufacturing processes and visiting points of use (Marcus, 1998). It required interviewing experts and outsiders, aficionados and lay people, users and non-users. Such sites for ethnographic inquiry offered a window into "decisions about encoding and standardisation, tinkering and tailoring activities [...] and the observation and deconstruction of decisions carried into infrastructural forms" (Leigh-Star, 1999: 382). In tracing the life of SHW in Thane and São Paulo this research engaged with sites of:

- ***Technological imagination***, such as government offices and programmes at national, regional and local levels as well as NGOs and business associations involved in the promotion of SHW.
- ***Technological strategizing***, such as energy utility companies, energy consultancies and electrical engineering firms, all of which are involved in envisioning how SHW interacts with electricity and its infrastructures and markets; this included industry conferences where agents gather to discuss the practical ways in which SHW is being incorporated into society.
- ***Technological development***, such as the factories behind the manufacture of SHW systems and the sites and agents in charge of selling, distributing and installing them.

- ***Technological use***, such as the buildings where SHW has been installed, the offices where housing developers commission SHW, the architectural and civil engineering offices where hydraulic configurations of buildings are being transformed to accommodate SHW, and the dwellings and bathrooms where SHW finds a moment of stability (and often invisibility) by delivering hot water.

This ethnography of infrastructure enabled an interrogation of complex processes that are usually taken for granted. It provided entry points for epistemological and political insights as well as more practical policy recommendations (Hess, 2001). An ethnography of infrastructure allows to see how infrastructure "sink[s] into other structures, social arrangements and technologies" and is embedded in social processes, supporting them in an invisible way (Leigh-Star, 1999: 381). It reveals how infrastructure has defined spatial and temporal reaches that often transcend a single event or one-site practice, while at the same time is 'learned as part of membership', or so to speak, takes form within a community of practice where elements are taken for granted or 'naturalised'. For example, urban energy and water infrastructures both shape "and [are] shaped by the conventions of a community of practice" (Leigh-Star, 1999: 381). Just like São Paulo's electric showers, popularised in a past of abundant hydroelectricity (Chapter 5), infrastructure generates lock-ins and practices that are transmitted to future generations. Such a methodological approach around the ethnography of infrastructure enabled the identification of a multiplicity of narratives. It required conversation as much as observation, as the traces "left behind by coders, designers, and users of systems" (Leigh-Star, 1999: 385), as well as those left by the materials composing, blocking and passing through them, were recorded and their passive and active voices identified. Such voices included the internal plastic piping that characterises dwellings in São Paulo and prevent the use of SHW by refusing to carry hot water; the buckets of Thane's bathrooms that minimise the amount of water used in daily baths and quietly limit the future flexibility of today's SHW systems; the hierarchy of water taps of Thane's bathrooms that denotes socio-economic level as much as water consumption, from simple taps at waist level to more complex ones attached to showerheads; and the water meters of São Paulo's social housing and their refusal to allow (solar) hot water through them.

4.5 Data Collection

Guided by the ethnographic sensibilities described above, the thesis used mixed methodological methods for data collection: participatory observation and project visits, interviews, research diaries, photography and a desktop review of background documents. Whilst in retrospect it is easy to separate each method, in practice they were all interconnected: a continuum within the everyday research experience of the fieldwork period. For example, interviews would often be part of – or lead to – project visits or instances of participatory observation and vice versa. The use of photography would be embedded within all other activities (including, on occasions, the interviews), and would also occur outside of them as the city itself was being recorded. Writing research diaries and records of site visits would be a permanent activity filling every spare moment. Such a variety of methods offered the benefits of triangulation, providing for additional rigour. Moreover, the constant exercise of these methods combined and blending into each other, not only constituted the traveling ethnography of urban infrastructures, but also enabled an in-depth immersion in the 'solar scene' of each city (Crang and Cook, 2007).

In Brazil the fieldwork was entirely within the city of São Paulo, with a base at the offices of Vitae Civilis. Day trips to other municipalities within Greater São Paulo were carried out as required, including Guarulhos and Cubatao. In India the fieldwork started in Delhi, where the headquarters of ICLEI-South Asia are located. After 4 weeks of direct interaction with ICLEI towards selecting the final research sites, the fieldwork moved to Thane where the majority of time was spent. However, fieldwork in India also included weeklong visits to Nagpur, where similar projects are being developed by the municipality in collaboration with ICLEI, and Bangalore, where the majority of Indian manufactures of SHW are located.

4.5.1 Participatory observation and project visits

In total, the fieldwork period allowed for 16 defined instances of participatory observation and 27 project visits (Appendix II). Rather than approaching participatory observation as an instance of separation between 'subjective' and 'objective' elements in the research, it was seen as "a means of developing *intersubjective* understandings between researchers and researched" (Crang and Cook, 2007: 37, original emphasis).

Before starting the fieldwork, I envisioned that the primary data collection method would be participatory observation through the everyday interaction with ICLEI and Vitae Civilis. My objective was to, as least for part of my time, become a member of staff working on one of the solar energy projects that each organisation was carrying out. However, once in India and Brazil, this objective was not realised as the solar projects that each organisation was working on were not active at the time of fieldwork: the projects were going through a quiet phase between two moments of high activity (in the case of ICLEI) or were mostly a thing of the recent past (in the case of Vitae Civilis). This made me into an adjunct 'member of staff' with a desk but no project to work with, and forced me to devise alternative strategies for carrying out the research. In both cases, staff members were extremely open and helpful, provided support in the process of selecting case studies (and cities, in the case of India) and offered access to their formal and informal networks of policy makers, practitioners and advocates working with solar technologies. The initial guidance provided by ICLEI and Vitae Civilis was invaluable, and the time spent in their offices allowed me to understand the broader context of energy in the city, how both organisations conceive their role in the promotion of renewable technologies, what mechanisms they use for this purpose and what forms of thinking guide their actions.

Through the practitioner networks of ICLEI and Vitae Civilis, but also by approaching other solar industry players directly by telephone after looking for their details on the internet or meeting them at practitioner conferences and events, it was possible to develop a lengthy list of potential organisations to visit with the aim of carrying out interviews, project visits and/or participatory observation. Participatory observation and project visits were a key mechanism for gaining an in-depth understanding of how different stakeholders interact with the technology in its different forms. Participatory observation allowed for the identification of practices of energy production as well as consumption, alongside the generation of a detailed account of the behaviours and relationships involved (particularly in the case of production, the primary focus of the thesis). Industry workshops and conferences were key instances of participatory observation, alongside training workshops on the manufacture and use of solar technologies and involvement in the installation of DIY SHW systems.

Project visits were a specific mode of observation, albeit with limited direct participation. They were carried out both as part of the scoping exercise that lead to the selection of cities and case studies, as well as within the context of the case studies themselves. The large majority of projects visited were SHW installations in residential buildings, several of them in low-income housing. Other projects visited included photovoltaic systems in municipal buildings, solar traffic lights and concentrated solar (solar parabolas). Given the nature of the primary research object (solar technologies), project visits included explorations of the roof terraces where the equipment is installed. The initial project visits focused more on the discovery of the technology, its basic understanding from an engineering perspective and the translation of this into lay terms. Over time, this gave way to a more subtle and nuanced understanding of how the technology shapes and is shaped by its use, and how it would interact with broader social dynamics. However, not all projects visited were related to solar technology implementation. They also included public display and information centres on renewable technologies, and even a factory of SHW systems.

4.5.2 Interviews

A total of 122 interviews were carried out, 64 in India and 58 in Brazil (Appendix II). These were open interviews, although guided by general interview schedules (according to type of actor) designed beforehand (Appendix I).

Interviews functioned as a key data collection mechanism, targeting specific actors involved in the rollout and use of solar technologies. When viewed from a distance, the main characteristic of the set of interviews carried out is the broad diversity of stakeholders interviewed: policy makers, advocates, users, solar aficionados, staff members of manufacturing companies, shop owners, energy consultants, building engineers, architects and staff members of utility companies, amongst others. Interviews allowed actors to generate an account of the experience of dealing with solar technologies from their own perspective, exploring the reasons and motivations behind their involvement, their satisfaction, perceived limitations and overall experience. The use of interviews allowed for gathering large amounts of data over a short period of time, while covering a broad variety of topics (Robson, 2002: 269-291). Gaining access to solar industry players was a straightforward task since, after one or two phone calls, they would be willing to receive me at their offices. The biggest challenge was to obtain access to users of SHW, as it was difficult to identify them. Once they were identified (through informal networks or after spotting a house or building with solar panels on it), not all of them would be willing to provide an interview as this would imply giving up part of their evening family time. Identifying users for the purpose of carrying out interviews was easier in Thane, where it is clear where SHW is being installed as this is occurring in the same areas of urban growth. In São Paulo growth is not concentrated in one or two zones, but scattered all across the city, making it very difficult to identify dwellings with SHW. In the case of users with social housing, access was achieved thanks to the support of the CDHU.

Whenever informants authorised it, interviews were digitally recorded (audio). The research used semi-structured interviews, which once under way framed a more open conversation. It is worth noting that the number of interviews is not indicative of the quality of the data. Some interviews provided valuable insights, others served to gain a better understanding of the context, whilst several proved to be of little use.

4.5.3 Research diaries

Every day over the course of the fieldwork period I would write detailed notes of my daily activities, both in relation to the research but also about daily life beyond the research itself (Figure 4.10). These would be complemented by my general impressions of the urban and national contexts, and a constant reflection on the research process. During fieldwork, keeping a research diary was a time consuming but enriching commitment which generated valuable information by providing a detailed record of how the research was carried out, allowing me to keep an eye on what I had done already and what I still needed to do. The diary was also useful for keeping track of the many people and projects I was contacting, meeting and visiting. In line with ANT's approach to research diaries (Latour 2005: 134), three types of diaries were kept, as follows:

I. ***General fieldwork diary:*** a 'log of the enquiry', recording daily activities, site visits, people met, appointments and impressions during the fieldwork period.

II. ***PhD diary:*** a record of writing trials and sketches kept over the entire duration of the PhD, recording ideas, draft concepts, metaphors and trials.

III. ***Digital register:*** a digital record for codification into categories, used during the data analysis and writing period, which allowed for reshuffling data in a variety of combinations without affecting the original data. This was done with the Nvivo software pack (Section 4.6).

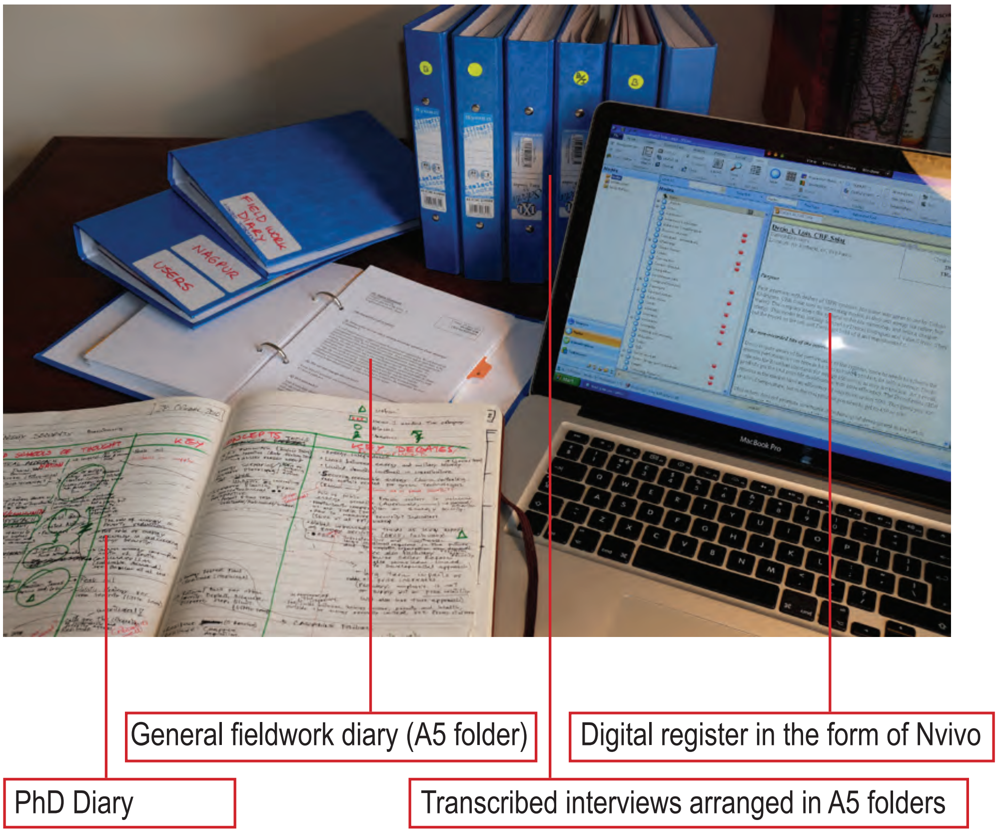

Figure 4.10: data pack, composed of research diaries and transcribed interviews

4.5.4 Photography

Solar technologies have the advantage of making energy visible in the city, pointing to the appropriateness of visual technologies as a methodological tool (Rose, 2007; Pink, 2006). Photography complemented the ethnographic approach and provided a tool for data gathering with an explicit focus on the material and technological dimensions of the research. Photography was used to record all project visits and participatory observation instances. It functioned as a data register (of technologies, sites, and moments), to complement observation, to support analysis by providing a visual record that can be accessed after the fieldwork phase, and to illustrate ethnographic descriptions and insights. However, whilst the original intention was to make use of photography in a more explicit way as a strategy for analysis, its final use is limited primarily to data recording. In this sense, photography played a *supportive* role only (Rose, 2007: 239). The traveling ethnography of urban infrastructure could make a better use of photography, but this would require a clearly defined visual strategy established before starting the fieldwork period.

4.5.5 Review of documents

Key policy documents were reviewed, providing an important local, regional and national context for the research. In the analysis of some case studies, policy documents functioned as key research objects providing primary data, such as in the case of the Thane Solar Cities Programme (case study 2). This was complemented with a desktop review of selected grey literature documents, obtained from the Internet and provided by the host research organisations.

4.6 Data Analysis

Analysing the data was a permanent and on-going process over the course of the entire research period. Data analysis was informed by the principles and methodologies of grounded theory (Cloke et al., 2004; Robson, 2002), in an effort to offer an empirically rich interpretation "deeply anchored… in the understandings of the participants as revealed in interviews or other accounts" (Cloke et al., 2004: 315). Drawing on grounded theory, coding (via the qualitative data analysis software Nvivo; Figure 4.11) was intended to be the primary form of data analysis. However, there were several other instances and processes that contributed to such analysis. To an extent, data analysis started even before the formal data collection had begun, as the desktop review of projects informing the selection of cities and case studies led, at the time, to an initial list of codes for future use in Nvivo. This initial list of codes evolved significantly over time, as new research questions would take shape and I would realise that such coding structure was too detailed and ambitious (Appendix III). Throughout the entire research the use of diaries was instrumental in the process of reflecting and analysing the data (Section 4.5.3). In addition, towards the end of the fieldwork and upon my return to the UK, the process of transcribing interviews also played an important role in data analysis, as it refreshed the fieldwork experience and allowed a form of analytical distance that resulted in the emergence of the key themes of the thesis.

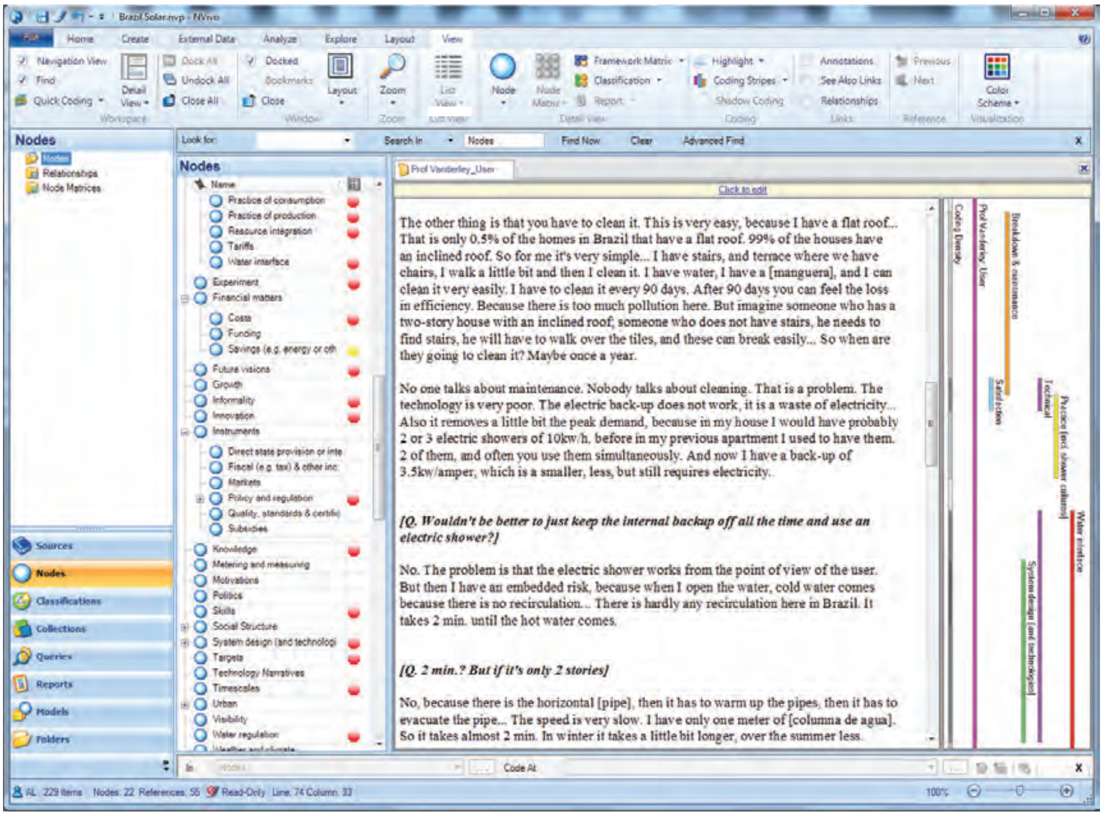

Figure 4.11: screenshot of Nvivo, showing a coded interview with a SHW user.

In retrospect, coding via Nvivo was a useful process, but it would be unfair to locate here the bulk of data analysis. Data analysis was iterative and constant, entangled with data collection and processing, with the identification of research sites, and with the development of conceptual frameworks. The coding process was useful in that it demanded an in-depth reading of transcribed interviews, fieldwork diaries and other notes, opening a space for reflection and generating analytical notes. But once the coding process had finished, Nvivo was, less an analytical tool, than a useful mechanism for navigating and rapidly accessing the data.

4.7 The researcher and the researched

This section discusses the ways in which local stakeholders engaged with the research, and presents a reflection on my role as a researcher and how my personal characteristics (as male, as Latin American and as a Spanish speaker) influenced the thesis. Any social science research informed by ethnographic approaches inevitably requires 'local' engagements. It demands visiting the sites of an imagined 'other' and there, in 'their' space, inquiring about 'their' viewpoints. Yet research also requires visiting oneself, and understanding how the personal positions (the sites) of the researcher play out in the sites of the 'other'. This reflection around my position and my interaction with the researched aims to situate the knowledge generated, acknowledging that "only partial perspective promises objective vision" (Haraway, 1988: 583). From this perspective, "situated knowledges are about communities, not about isolated individuals. The only way to find a larger vision is to be somewhere in particular" (Haraway, 1988: 590). The following paragraphs examine these topics in more detail, focusing on the role of local research partners, dissemination tools, and positionality.

4.7.1 Applied knowledge generation: working with local research partners

The fieldwork phase was carried out with the support of two environmental non-profit organisations promoting the use of solar technologies in Indian and Brazilian cities: ICLEI – Local Governments for Sustainability in India and Vitae Civilis in Brazil. These host organisations served as local research partners, provided office support (space and communications) and general guidance during the fieldwork period. In India, the South Asia office of ICLEI was an appropriate research partner given its significant involvement in the implementation of the MNRE's Solar Cities Programme. Based in Delhi, ICLEI was appointed by the MNRE as the consultant in charge of managing the specific Solar Cities process (and preparing the Solar City Masterplan) for 12 of the participating cities, including Thane and Kalyan-Dombivli in the Mumbai Metropolitan Region (ICLEI-SA, Undated). In Brazil, since 2005, Vitae Civilis has played a key role in lobbying municipal governments for the adoption of solar technologies. Between 2006 and 2010, along with DASOL, Vitae Civilis hosted the Brazilian Solar Cities initiative, a network of researchers, activists and practitioners promoting the development of local legislation on solar technologies (Cidades Solares, Undated). Vitae Civilis was instrumental in São Paulo's process for adopting the Solar Law .

Working with two practitioner organisations greatly facilitated the development of the research. Undoubtedly, their activities and viewpoints coloured the research outcomes. The interaction with them influenced decisions regarding research sites and pointed to particular sources of information and not others. Overall, they provided invaluable help in the development of the Thesis.

The fieldwork phase of the research generated applied practitioner reports on best practice case studies around solar technologies, contributing to the host organisation's efforts of promoting solar technologies. In the case of ICLEI, this material became part of the organisation's set of online case studies on local sustainability, and were included in a publication launched at the Rio+20 - United Nations Conference on Sustainable Development (broadly distributed amongst local governments worldwide). The fieldwork phase also generated other case studies published in practitioner journals with high circulation amongst local governments (Appendix IV).

4.7.2 Multimedia tools: dissemination of results

In addition to reports on best practice, the research developed a dedicated website for research dissemination. The website is called 'New Energy Geographies' (www.energygeographies.com; Figure 4.12). Its primary purpose is to provide a medium term platform for research participants (e.g. informants and host organisations) and other interested stakeholders to be able to access in one single site all research results and publications (academic and non-academic) generated by the thesis. During the fieldwork phase the website also functioned as a blog, providing research updates. Since it is likely that research outcomes and publications will continue to be produced for a few years after the completion of the thesis (e.g. in the form of academic articles), the website has been scheduled

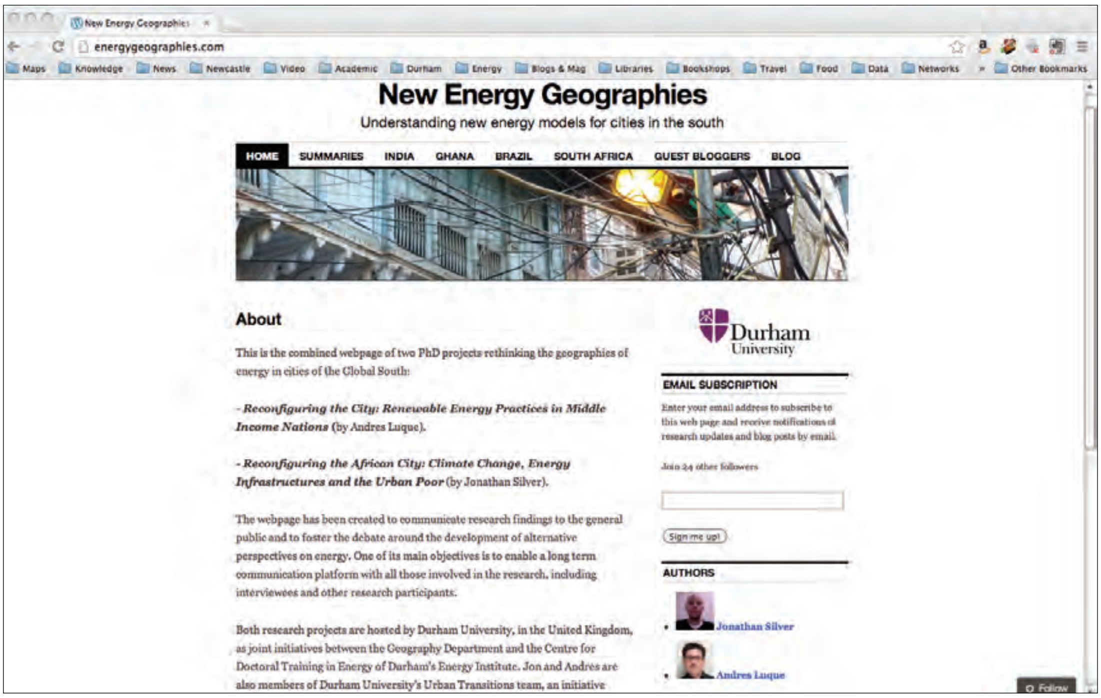

Figure 4.12: New Energy Geographies website.

to function until the year 2016. All informants were given a personal card with my contact details as well as those of the website, with the objective of pointing them towards this Internet platform for accessing research outcomes as they are published.

The website is a joint initiative with Jon Silver, also a PhD student at the Geography Department of Durham University, whose research covers similar topics in the cities of Accra (Ghana) and Cape Town (South Africa). Through this comparative structure, the website also intends to foster the debate around an alternative understanding of the geographies of energy in cities of the Global South.

4.7.3 Positionality

Positionality has been defined as the way in which "a researcher's social, cultural and subject positions… affect: the questions they ask; how they frame them; the theories that they are drawn to; [and] how they read" (Pratt, 2009: 556). It refers to how the researcher's subjectivity affects the way in which knowledge is created, and the extent to which this process is affected by our positions of power and our own specific viewpoints. Positionality is also related to the cultural differences or commonalities between the researcher and its research space, which might influence the research process and its interpretation. Being male, Latin American, and with a limited knowledge of the local languages shaped my vision, as much as it shaped how I was seen. In doing so, it played an important role in shaping this research as detailed below.

Gender

With the exception of the domestic spaces of use and consumption, the sites where solar technologies were being imagined, manufactured and implemented were occupied primarily by men. As a result the large majority of interviewees and informants were male (for example, women participated in only 19 out of the 122 interviews carried out). Access to these spaces and sympathy from interviewees was undoubtedly facilitated as a result of my gender as male. At the same time, access to some of the spaces where hot water is used (such as kitchens) was limited given my gender. It is necessary to leave an open question regarding the way in which gender influenced and affected the research's fieldwork. This opens broader questions about the interface between gender, technology and low carbon transformations.

Ethnic and national background

My background as Latin American influenced the selection of research sites, given a personal interest in advancing research in the Latin American region. It also influenced the relationship with informants, as a shared identity (as Latin Americans in Brazil, or as 'equal representatives' of a 'developing world' in India) would often ease the relationship by creating a form of familiarity and empathy. Doing field research in India and Brazil was facilitated by my Colombian nationality, as conversations and engagements with local research partners and informants were configured outside tensions around power relations within North-South knowledge generation. After inquiring about my origin, informants in both countries would often welcome the research inquiry as a form of South-South knowledge exchange. This was more obvious in Brazil, where another South American would often be welcomed, despite the many questions that he had to ask. This empathy between researcher and informant was often increased by my previous research experience in India (fieldwork in Brazil was carried out immediately after India), as many Brazilian informants were genuinely interested in hearing about the ways in which the solar industry operates in India. This empathy points to both a desire and potential for South-South knowledge exchange. In India sometimes the location of my main research institution, Durham University in the United Kingdom, would overshadow my national background, and I would be able to sense how the informant was seeing me as a foreign researcher coming from a northern and western nation. But this was not always the case, and often interviews or project visits would finish with two-way information exchanges on the contrasts and similarities between South America and India. In an informal way, these conversations were another way of reflecting around the comparative urbanism dimension of the thesis. They would inevitably influence the data collected, particularly the emergence of key research themes (e.g. social agendas vs. urban growth). All these small forms of South-South cultural exchanges accounted for some of the most rewarding moments of this thesis.

Language

Several languages were involved in the course of this thesis, from my own native Spanish and Brazil's Portuguese, to Hindi, spoken in Delhi and Mumbai, and Marathi, the predominant language of Thane. English was the main research language during the fieldwork in India. ICLEI, my host organisation, as well as the government agencies (at local, regional and national levels) and business (both small and big) that I interacted with in India operated normally in a bilingual way. In the case of SHW users in Thane, language was not a barrier either. As discussed in Chapter 7, SHW technologies in Thane sit exclusively within the domain of the middle classes, where English is normally spoken. My lack of Hindi or Marathi was more of a limitation when trying to identify and establish contact with users of solar technologies, as this would require visiting residential buildings and talking to porters and other 'gatekeepers' in order to gain access and identify the right point of contact for an interview. In these cases, friendships developed over the course of the fieldwork took the role of research assistants, and accompanied me to site visits. The lack of language was also a limitation during some participatory observation instances around the installation of SHW, since the installers would be local technicians with no knowledge of English.

In Brazil the research was carried out in Portuguese. My knowledge of Portuguese is limited, despite lessons taken before starting the fieldwork phase. But the similarities between Portuguese and Spanish enabled me to adapt quickly to a form of language that, far from being a perfect Portuguese, performed an appropriate mode of communication over the course of the fieldwork. All interviews in Brazil were carried out in Portuguese and translated into English at the time of transcription.

Overall language was not a barrier, but this was largely related to the type of informants that were being interviewed given the broad research framework established. Clearly a research framework that would shift the research's emphasis from the spaces of imagination and implementation of solar technologies to those of use would require a greater engagement with local languages.

Together, positions around gender, ethnicity, nationality and language created a particular – and unconscious – research identity performed over the fieldwork period. This was a research identity that would rely on the enactment of equality within difference; on proximity, whilst highlighting distance, as the way in. Despite coming from a different space, the researcher (me!) and the researched were made to feel one and the same. Bridging distance (difference) was about exchanging worldviews; sharing viewpoints. Beyond being a friendly outsider or a curious visitor, the researcher was simply coming back to an imagined home. For me, on reflection, the way by which identities are unconsciously constructed and performed during the research practice and operate as strategies for access is a surprising discovery. More surprisingly, these performed research identities speak of who we, as researchers, want to be.

4.8 Summary

In practice, the approach taken to the PhD research consisted of an ambitious methodology, not exempt of challenges, tensions, anxieties and physical strain. Looking back on this traveling ethnography, there are three relevant lessons. First, the inevitable tension between ethnography and comparative urbanism. The research pushed the boundaries of both. Ethnography stands as a useful tool for comparative urbanism, by facilitating a full immersion that accounts for a steep learning curve and providing a research experience rich in data. Yet the timeframes that allow for multi-sited research can clash with the demands of an ethnographic approach. Further experimentation with forms of 'traveling comparative ethnographies' is required to ensure that this tension is resolved in productive ways.

Second, the balance between research methods within this form of comparative ethnography needs to be kept in check, particularly when combined with specific forms of data analysis. In this thesis, a slight emphasis on interviews was brought forward as a way to deal with the tensions between ethnographic dwelling and comparative urbanism. The use of Nvivo as a tool for analysis foregrounded interviews as the primary data source. In practice, at the time of writing, this overshadowed the potential of the ethnographic approach. Mechanisms to embed further the ethnographic contribution are required.

Finally, a reflection needs to be made in relation to the role of national scales in determining the objects of comparison. This is of particular relevance for a thesis that examines the ways in which power operates across scales, in an attempt to denaturalise them (Section 3.6). Given the prominent role of national constructs (Brazil and India) in the definition of research sites (São Paulo and Thane), it is impossible to escape a theoretical challenge associated with the way in which pre-existing city-state relationships configure the object of study: "to what extent and in what manner must cities be understood in reference to their states?" (Nijman, 2007: 4). Here the lesson is that, despite an explicit attempt to embrace notions of cosmopolitan urbanism where cities are 'ordinary' in spite of their national context (Robinson, 2006), the national scale still plays a significant role in shaping the city and what we can learn from it. Multi-scalar problems such as those defined by the energy and climate change interface denote urban responses that are necessarily conditioned by national and international interests (Sections 2.4, 3.2 and 5.3). Yet it is important to avoid falling into a trap where a comparison between Thane and São Paulo is meaningful only because of their specific location within national economies. Comparing São Paulo and Thane is also a methodological position that operates as a refusal to blanket claims around the need for shared historical, political or contextual similarities as prerequisites for urban comparison. In opposition to a logic of comparing 'world' or 'global cities' (Sassen, 2001; Taylor, 2004), where São Paulo and Mumbai as international nodes of finance would have been the obvious comparative choices, comparing Thane and São Paulo through a 'cosmopolitan urbanism' (Robinson, 2006) approach disrupts this logic by comparing the small and the large, the peripheral and the central, the bounded and the loosely bound.

Comparing São Paulo and Thane is also an attempt to generate South-South knowledge and learning. Paraphrasing Lees (2012: 156), this South-South dimension of comparative urbanism takes us away from an 'imitative urbanism', "from the idea that [the low carbon urban energy transformation] in the Global North has travelled to and been copied in the Global South". Instead, it leads us towards an intellectual space "where [such transformation] in the Global South has a more expanded imagination".

Chapter 5

The urban energy problem and the emergence of the local governance of energy

5.1 Introduction

This chapter focuses on the problematisation of energy at the urban scale, and the emergence of eco-technical constructs around solar technologies as the preferred solution. In doing this, it uncovers three governmental rationalities involved in the emergence of the solar energy regime. These are, first, issues of resource constraints; second, climate change; and thirdly, energy demand. The chapter illustrates the ways of thinking that lead to the emergence of a local energy regime, which stands in sharp contrast to the centralised energy regime examined in Chapter 2. In Brazil and India, unlike other resources that normally operate within the domain of local planning, such as water and waste, energy has been largely absent from the governing practices of local authorities. Recent developments suggest the emergence of local energy regimes in selected cities such as Thane and São Paulo.

The chapter first analyses how energy comes to be seen as an urban problem, both as a strategic dimension for a city and a national problem that requires an urban intervention. Second, it examines how solar technologies, through their material and symbolic qualities, come to be selected as the preferred solution. The chapter argues that the local problematisation of energy and the identification of solutions that are intimately connected to local agendas and geophysical conditions are related to the emergence of a new geography of energy.

Within this geography, the spaces for governing energy (collectively thinking about, acting upon, controlling and redistributing) are being reconfigured.

The chapter is structured in three sections. It starts with a brief introduction to the ways in which notions of episteme, ethos, visibility and telos are used to understand processes of problematisation (Section 5.2). The chapter then turns to consider the three rationalities guiding the local problematisation of energy (Section 5.3). Each of these rationalities is illustrated through empirical material from one city, suggesting that that rationalities are locally specific and that, despite some commonalities, they are more or less important at different times and contexts. The resulting way of configuring the energy problem is one where local domains, from the city to the dwelling, are seen as key entry points for the reconfiguration of the energy system. The local problematisation of energy has brought about a renewed way of governing energy, this time with the city and its dynamics operating as a focal node. The chapter finishes by considering how decentralised solar technologies such as SHW have become the preferred solution to the local energy problem (Section 5.4). This is the result of solar technology's ability to intervene in the material and symbolic domains of the city. In the case of São Paulo and Thane, the research finds that SHW interventions put in place a local energy regime that operates by mobilising new ways of thinking about – and relating to – resources in three ways. The first is by opening up the possibility of re-deploying the relationship between nature and the city through infrastructures that acknowledge local geophysical conditions, ecological cycles, seasonality and uncertainty. The second is through creating an opening for re-thinking material flows in the city, generating a series of efficiencies associated with resource integration, particularly through the integration of water and energy systems and the recognition of the energy embedded in water. The third is by mobilising the power of solar energy in the service of pre-existing broader agendas, such as urban growth or housing provision. In the case of Thane, the symbolic power of solar energy establishes a new set of eco-technical imaginaries that, while supporting the urban growth agenda, allow the re-thinking of issues of modernity and autonomy in service provision. In São Paulo, solar energy jointly addresses national and local needs, offering an integrated way to respond to national concerns around peak demand and local housing provision.

These new ways of thinking about energy and relating to resources transform the city, from being a space exclusively of demand to become a node for energy generation and the development of solutions to the energy problem. Yet, through this analysis, the chapter illustrates how seemingly similar urban problems at a global scale have very different local expressions. Arguably, several cities around the world are facing comparable challenges in relation to resource constraints, climate change and energy demand. Thane and São Paulo provide contrasting examples of the multiplicity of ways in which these challenges, and the rationalities associated with their constitution as domains in need of intervention, are being distinctively perceived and acted upon.

5.2 Energy as an urban problem

An analytics of governmentality unpacks the ways in which issues are rendered problematic. By examining the way in which energy is problematised in the city it is possible to understand "the conditions under which [local energy regimes] emerge, continue to operate, and are transformed" (Dean, 2010: 33). In the case of the transformation of urban energy infrastructures, a governmentality framework starts by examining how the urban energy problem is being rendered thinkable in ways that lead to technical solutions (Miller and Rose, 2008: 16). These governmental rationalities, or ways of thinking, establish what needs to be changed, why and through which means (Section 3.4). In Thane and São Paulo, the emerging solar energy regime is constituted by three rationalities: climate change, issues of resource constraints and security, and energy demand. These rationalities have an existence beyond the regime, yet the regime makes them into constitutive elements; pins them down and articulates them. In this sense, rationalities operate at different levels. The dimensions of governmentality examined in this chapter – episteme, telos, visibility, and ethos – provide a way to unpack and understand how the regime draws upon the rationalities. They offer a window to how the regime operationalises the rationalities, providing a detailed analysis of how the problematisation of energy in Thane and São Paulo gives shape to an emerging local governmental regime around solar energy.

5.2.1 Energy discourses through multi-sited problematisations

Like a discourse, problems are constructed from a multiplicity of different and dispersed statements, sites and viewpoints. Such dispersion, rather than a symptom of fragmentation, is an indication of their unity (Legg, 2007b: 39). The local energy problem, as well as the idea of using solar objects as its solution, emerges through a variety of debates and discussions. Key concepts, such as energy security, energy efficiency and environmental conservation, cut across all the governmental rationalities involved. In this way, they function as strategies for organisation towards achieving conceptual and theoretical coherence (Foucault, 1972). This process of problematisation and intervention constitutes the object itself. Further, the identification of objects for governing – for example, solar energy – embeds an understanding of how the object is constituted and how it relates to other objects (Lockwood and Davidson, 2010: 390; see also Miller and Rose, 2008: 15).

5.2.2 Episteme, telos and visibility as tools for understanding energy in the city

The different governmentality dimensions introduced in Section 3.3 serve to conceptualise the emergence of the solar energy regime. Episteme, as the multiple ways of thinking and questioning the governing activity, link directly to the process of problematisation. Looking in detail at such problematisation reveals how thinking about energy in the city is informed by the development of specific energy knowledges in relation to present consumption and future needs. This is, therefore, knowledge about abundance, deficiencies and capacities. For example, the discussion around such knowledge is mobilised at particular moments of growth, when capacity is required, and crisis, when deficiency takes over. Charts and graphs become a material manifestation of thought – and truth – as peak demand curves, capacity charts and resource maps give a tangible expression to the energy crisis, the need to intervene, and finally the 'evident' solution (see for example Figures 2.5, 2.6, 5.21 and 5.22).

Governing solar infrastructures has the aim of building a better society – the telos dimension of governmentality. Solar technologies are used as a symbol for utopian visions and ideas of the city. They are mobilised through their visibility, with the objective of representing the city in particular ways. In line with the earlier discussion on the ways in which urban infrastructure configures the city, where the material power of infrastructures becomes a symbolic power in support of urban modernities (Section 3.2.1), the telos dimension of governmentality points to how solar energy carries a utopian and symbolic power beyond its materiality. The local governance of energy develops new ways of seeing energy, representing reality and highlighting certain objects (as opposed to others) in the creation of a specific futuristic notion of the city.

5.2.3 Localising energy security and the ethos of the solar energy regime

One important concept that cuts across the three rationalities underpinning the local problematisation of energy is the notion of energy security and its implications for the urban scale. Energy security discourses have traditionally been defined within a geopolitical framework and framed by a national perspective (Bradshaw, 2009; Mitchell, 2008; Stirling, 2010; Hughes, 2009; Yergin, 2006). Such approach has been criticised for placing an undue emphasis on the security of supply and disregarding issues of demand (Bridge et al., 2013). However, energy scholars and development organisations alike often highlight the links between growing urbanisation, an increase in energy demand and energy security at a national scale (Pachauri, undated; World Bank Group, 2009; OECD, 2008). In response to these security threats, organisations working on urban issues have advocated an increase in the use of decentralised renewable energy infrastructure in cities (ICLEI, 2010; UN Habitat, 2009). Experience from both Thane and São Paulo shows that, when enacted at a local level, this energy security discourse prioritises issues of demand over supply. This move is aimed at the identification of new balances in the production-consumption equation (see Sections 5.2 and 7.4).

Yet national and local energy agendas merge in manifold ways: local energy security discourses are deeply related to and informed by broader discourses on national energy security, and to the overall ability of both nation and city to meet growing demands. In the 'localisation' of energy security, local and national agendas meet. However, the type of local insecurities targeted out of this encounter of energy agendas – such as, for example, poverty alleviation, energy poverty or other forms of insecurity in domestic domains (Bouzarovski–Buzar, 2009; Buzar, 2007; Walker and Day, 2012; Bazilian et al., 2010) – deserves detailed analysis. Unpacking the ethos of the energy regime, through an examination of the forms of demand that are problematised in the emerging local governance of energy, points to the way in which the governmental rationalities of energy relate to local concerns.

5.3 The governmental rationalities that constitute an urban problematisation of energy

Energy as a local object emerges through three specific debates, drawing on broader governmental rationalities. First, it emerges as part of a discourse on resource constraints. Second, it is conceived within the problematisation of energy demand. Finally, it takes a central role within the emergence of climate change agendas in the city. These rationalities act as drivers guiding a multi-sited problematisation, giving rise to a new regime – specifically, a localised mode of energy governance. Both in India and Brazil, resource constraints play a significant role in shaping the national energy agenda, signalling the need to take action towards addressing long-term (multi-annual energy planning) and short-term (daily demand profiles) gaps between supply and demand. The expression of these concerns in Thane and São Paulo rests on the need to secure the means to safeguard important inputs for the development of local agendas. Re-thinking energy demand implies acknowledging the energy implications of local consumption practices, and drawing scalar links between national energy strategies, local needs and everyday 'mundane' practices such as showering with hot water. Climate change operates as a narrative that links global and local concerns (including concerns around finance), enabling local energy narratives to travel beyond their local reach. Together, these three rationalities and the respective problematisations implied by them – their episteme – provide the initial points of reference that constitute the solar energy regime, where solar technologies are a primary object of governing.

5.3.1 Thane: resource constraints and the localisation of energy security

This section examines the role of India's growing rate of urbanisation in causing energy to emerge as an urban problem. Securing energy for cities signals the need for locally planned energy, pairing the concepts of urban planning and energy planning. Rising concerns at the national level about the inability of the country to meet growing energy demand find echoes at the local level, where limitations in electricity capacity appear as a local problem standing in the way of urban growth. In response, Thane has embarked on efforts to plan energy locally. Framed by a history of load shedding, solar technologies are emerging as a possible way for Thane to take control of its energy challenges. Here national and local energy dynamics find common ground, as the city is seen as an appropriate space for interventions capable of contributing to solving a national energy crisis.

India's looming energy crisis: rethinking the role of the city

Urbanisation, in its current form and intensity, is a recent phenomenon in India. In the 1970s, the ratio of urban to rural population was 20/80. The energy problem was primarily a rural problem (Chapter 2), as the country strived to achieve full electricity coverage by pursuing the modernisation of agriculture and rural electrification (Bhattacharyya, 2006). As the urban to rural ratio changed, so too did the nation's power politics. In 2012, this ratio was 30/70, and is expected that by the year 2040 the ratio will be 40/60 (UN Habitat, 2013). India's rural to urban transition is occurring in the midst of a looming energy crisis. Accordingly, with projected growth trends, energy for cities has become a new national priority.

Indian government officials at national, state and local levels are acutely aware of how electricity constraints create a significant bottleneck for India's growth prospects (Government of India, 2006: xiii; see also Section 2.3.3). For the past decade, India's Ministry of New and Renewable Energy (MNRE) has been exploring options to promote renewable energy technologies in cities in order to address the growing gap between demand and supply. As the Director of India's Solar Cities Programme (Interview P1)[11] puts it: "India is growing very fast, 8 to 9, 10% GDP growth rate every annum. And India needs power. Power generation capacity is not increasing as per the growth of the country. So there is a power deficit". Urban, economic and industrial growth are compound factors putting

[11] All quotes from Indian interviews and primary sources are exact transcriptions, thus retaining national and regional specificity with regards to English usage. To respect such language forms, the grammatical form [sic] has not been used in the thesis.

pressure on the ability of the country to meet growing energy demands, and the country's rural to urban transition has been identified by the MNRE as one of the main energy challenges faced by contemporary India:

> *In Indian cities the GDP is growing at a very fast rate, and maybe within the next two years it will reach a two-digit figure. This is causing the exodus of villagers to the cities, and in turn, urbanisation. The rural people come to the cities for livelihood. …Urban planning is one of the most important and crucial things which needs to be done. We are trying to introduce renewable energy into the mainstream planning of the cities (Interview P1).*

The quote above shows how the urban is problematised in the context of energy. The city, through its rate of urbanisation and its characteristically high-energy demand, comes to be seen as both an energy problem and its solution. The response is to promote the use of renewable sources, with the city as one of the new targets for renewable generation. The push for renewable energy in cities is not seen as a mechanism to replace traditional grid-based supply, but as a supplement that can contribute to meeting the overall energy needs of a rapidly growing economy, "…in this way we wanted that wherever and whatever possible in a city, to [use] renewable energy, we must utilise that" (Interview P1).

The Director of the Solar Cities Programme at the MNRE explains how the objective of the programme is to incorporate energy planning at the local level, an objective that goes beyond just funding renewable technology projects: "We are trying to introduce energy planning into the planning process… I would not say that we are giving some funds for putting renewables. No" (Interview P1). This quote suggests that cities are being pushed by the central government to look at energy as a matter of urban planning and to take a proactive role in thinking about energy issues. It represents an ethos guiding the orientation of the programme. In this way, through initiatives such as the Solar Cities Programme, the national government has acknowledged issues of limited supply in the context of demand growth, and is turning to the city as one of the spaces for managing the gap between supply and demand.

Thane: load shedding as a local constraint

The concerns voiced by central government officials in India over an energy supply crisis are shared at the local level. Historically, Indian cities have seen their productivity and growth prospects curtailed by a lack of electricity (Section 2.2). Thane is not an exception. Load shedding is a common event in the life of the city. Within a context of rapid population and economic growth as well as urban expansion, discourses and debates on energy emerge as the city looks for ways to secure its urban growth agenda. However, in Thane energy security is as much local as it is national, as suggested by the director of the city's Electrical Engineering Department who highlighting during an interview the security dangers associated with the large percentage of imported energy in India. His remarks on energy security are followed by a propositional statement around the role of the local in energy provision: "we have to address the issue through indigenous sources such as solar energy" (Interview P11).

As a city that for the past two decades has embraced a growth agenda, Thane has been forced to think about energy in novel ways. When asked about the motivation for Thane's energy initiatives, the elected leader of the city's legislative body explains that the municipality has foreseen the high future requirements of energy, and, given supply limitations, is looking for ways to respond to this constraint: "we are stepping ahead and foreseeing the future. There is scarcity of electrical capacity in the city, in the states, and in the country. We cannot generate the demand required" (Interview P7).

The city's persistent load shedding and growing energy rates are commonly cited as justifications for the variety of local energy initiatives implemented. Media accounts from October 2011 reported an electricity shortage in the state of Maharashtra of between 3,500MW to 4,000MW of power, nearly 25% of its total demand (Daily News Analysis India, 2011). Developing local energy projects was seen in this context as a way of experimenting with different modes of energy security at the local level, often justified by the need to develop alternative systems capable of securing resource access in a situation of intermittent provision. This includes biogas electricity plants, solar powered traffic lights, solar air conditioning and hot water for public hospitals, and solar PVs for the municipality's offices (Figures 5.1 to 5.5). "It increases the reliability of power supply", commented Thane's Director of Electrical Engineering, praising the recently installed solar powered traffic lights and commending the solar lights provided at the city's dispensaries, "also… very reliable. Patients were getting deprived because we cannot afford a generator there" (Interview P11).

Figures 5.1 and 5.2: Biogas electricity generator powering Thane's main public hospital and solar traffic lights.

Figure 5.3: SHW systems at Thane's main public hospital.

Figure 5.4: Solar parabolas for air conditioning at Thane's main public hospital.

Figure 5.5: Solar PVs on the main building of the Thane Municipal Corporation.

Planning for growth in the midst of limited capacity

Alongside load shedding and higher energy prices, electricity distribution capacity and the constraints imposed by an ageing infrastructure also played an important role in the city's decision to experiment with solar technologies. Thane's most recent publicly available City Development Plan (as of 2013) was prepared in 2006 within the context of the Jawaharlal Nehru National Urban Renewal Mission (JnNURM), a national-level city modernisation scheme. The plan has two interlinked priories: infrastructure and economic growth. This is expressed as "the sustained economic growth of the city... along with the expansion of services commensurate with the pace of urban population growth" (Thane Municipal Corporation, 2006: 115). Combining a business language – focused on seeking ways to engage the private sector in urban development – with ecological modernisation discourses, the plan states that its goal is to "accelerate [the] eco-growth of [the] city in an equitable and sustainable manner" (Thane Municipal Corporation, 2006: 92). The constraints imposed by the city's limited electricity capacity were seen in the plan as a threat to the proposed growth. The plan states that the existing 22/11 kV transformers "have just enough capacity to meet" the city's peak demand of 190 MW, whilst the "network is 30 - 40 years old and deteriorated causing frequent interruptions" (Thane Municipal Corporation, 2006: 74, 76).

The City Development Plan establishes an ambitious objective of power self-sufficiency for the electricity needs of the Municipality's operations and uninterrupted power supply. It argues that these ambitions are to be achieved via additional infrastructure provision and non-conventional energy sources, an objective that inspired the development of the city's Solar Law:

> *The city is developing with tremendous pace in all sectors, to keep the pace of development adequate and uninterrupted power supply is of immense importance. It needs additional infrastructural provisions.*

Alternate non-conventional energy sources need to be implemented. Energy conservation measures need to be effectively implemented…

The acute shortage of conventional energy leading to power crisis inspired TMC to supplement the gap by utilisation of non-conventional sources of energy i.e. the solar energy.

City Development Plan,
Thane Municipal Corporation (2006: 76 & 158)

The quote above illustrates the ways in which solar objects emerge within urban debates. Issues of resource constraints and limited access operate as a broad rationality, framing the development of local energy solutions. Energy shortages endanger the ability of the city to maintain economic growth and service delivery, and the city responds by mobilising discourses of energy efficiency, decentralised supply and renewable resources. However, solar technologies are not the only object that is made visible in the process of developing a local energy regime; practices of energy consumption are made visible as well.

5.3.2 São Paulo: peak load demand and everyday consumption practices shaping electricity networks

The second rationality behind the urban problematisation of energy is the recognition of the role of everyday consumption practices in the makeup of electricity networks. This is examined through a brief analysis of how showering practices in Brazil, highly reliant on the use of electric showers, impose constraints on the electricity network through the creation of a steep daily peak demand curve. In the context of abundant hydroelectricity (Section 2.2), the electric shower became ingrained in local building codes as the primary mechanism for heating shower water, which has played an important historical role in shaping São Paulo's electricity network. The problematisation of the energy demand caused by the daily practice of using electric showers has led to exploring the possibility of scaling up alternative water-heating mechanisms such as SHW via key urban dynamics, particularly social housing. In doing this, a specific ethos becomes embedded in the local governance of energy: the use of renewable energy forms in the context of social agendas, targeting low-income population.

Brazil's electric showers: domestic technologies shaping the energy network

São Paulo's electricity networks have historically been designed with one thing in mind: the need to cater for a cheap and simple domestic technology for water heating, the electric shower. In contrast with Thane, where rapid urbanisation links the urban energy problem to supply capacity, São Paulo's energy problem is framed not only around issues of supply but also demand. Specifically, it rests on the interface between techno-culturally defined modes of consumption and the country's electricity network.

The representatives of the Brazilian Electrical and Electronics Industry Association (ABINEE) interviewed for this research argue that the electric shower was invented in Brazil in the 1930s and first commercialised in São Paulo in the 1940s (Interview D17). It found its commercial niche thanks to the country's electricity surplus of the 1970s and 1980s (Chapter 2). Over 80% of Brazilian dwellings use hot water for showering purposes; 73% use electricity for heating water and 99.6% of these use an electric shower for this purpose (Andrade de Souza, 2009). The Brazilian government estimates that, by 2001, there were 40 million electric showers in operation. It is expected that this figure will increase to 70 million by 2030. In São Paulo, it is predicted that by 2030 electric showers will account for 24% of the city's residential electricity consumption (Governo Federal do Brasil, 2010b: 100). This pervasive domestic technology, easily available in supermarkets and local hardware stores, sells for as little as eight British pounds (Figures 5.6, 5.7 and 5.8). As two activists of solar technologies explain when discussing the popularity of electric showers, Brazilian electric showers are 'a small miracle':

It is a miracle, because, which other country in the world allows for its entire population to take a hot water shower at night? Only Brazil, because the electric shower costs R$15 (Interview P32).

The electric shower works very well. Despite consuming a lot of energy, it is very practical. It functions. It is easy to install, heats up well, and is cheap; very very cheap. So people don't think about putting in another system (Interview P35).

Figures 5.6 and 5.7: Electric showers on sale at a supermarket and local hardware store, São Paulo.

Figure 5.8: Electric showers at a supermarket, on sale from R$35 to R$21.90 (8 British pounds).

The popularity of the electric shower is the result of its affordability, widespread availability and ease of installation. As a water heating technology that operates at the point of use, electric showers do not require hot water piping. This lowers construction costs by avoiding the use of copper piping in the dwelling, and eliminates the need for specialised knowledge for installation. When compared to other water-heating technologies, such as the electric boiler, they provide greater efficiency and therefore are cheaper to run, "so the consumer, without throwing too many numbers, has the perception that the electric shower is a cheap product", as explained by the representative of ABINEE, which also owns a factory that manufactures electric showers:

> *When you have central heating, you need metallic piping to make the hot water connection. Therefore, it is expensive piping. When you use the boiler, you need qualified labour to install the system. That doesn't happen with the electric shower. You use plastic pipes. It [the water] leaves the cold-water tank and goes to the point of use through plastic pipes, therefore it is a simple and cheap installation (Interview D17).*

The electric shower used in Brazil looks like an oversized shower head with simple electrical components (Figure 5.9). It uses an electric current to heat up a metal resistance located inside the shower head. As cold water moves from the pipes and through the shower head, the water warms up because of its physical contact with the heated resistance. Since the electricity is immediately transformed into heat (hot water) at the point of use, there is limited scope for losses, giving electric showers efficiencies of over 95%. In Brazil, electric showers are available from 2,500 to 7,800 watts of power. A typical 5,500 watt shower provides a ~20°C increase in temperature with a consumption of 3 litres of water per minute (a relatively low water consumption level). This means that if the water entered the shower head at ~20°C it will leave the shower head at 40°C, an appropriate temperature for shower purposes, achieved via minimised water flows. The electric shower is praised by the electrical industry as a water saving device; for 'greater comfort' through a slightly higher water flow (i.e. 4 litres per minute) or for slightly colder conditions (i.e. water entering the shower head at less than ~20°C), an electric shower with 7,800 watts of power would be required.

Figure 5.9: Components of an electric shower.

Yet despite their high efficiency, electric showers demand a significantly large amount of power (energy per minute) to function. Those 7,800 watts over a 10-minute shower correspond to 1.3 kWh, approximately the same amount of electricity required to power an old domestic fridge and over twice the amount required for an A++ rated fridge. However, in contrast to the fridge, which is switched on for the entire day, the electric shower consumes such amount of electricity over a period of 10 minutes (the typical duration of a daily shower). To get an idea, using a 7,800 electric shower is the equivalent of switching on 78 incandescent 100 watt light bulbs all at the same time.

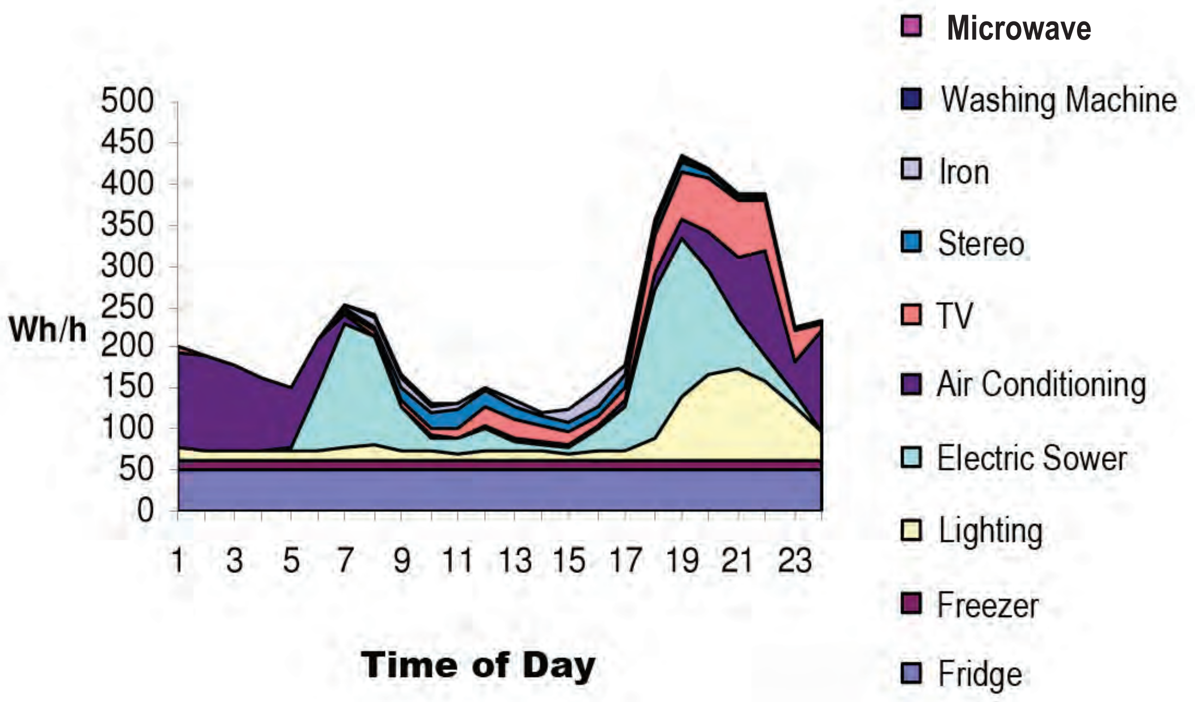

Figure 5.10: Electricity demand curve and peak load (residential), Brazil (Procel/Eletrobras, 2007: 18).

This high electricity demand makes the electric shower responsible for a significant portion of Brazil's steep daily peak demand load, which in turn is the main challenge of Brazil's national electricity system. Knowledge around the peak is made visible by Eletrobras through charts and diagrams that circulate broadly in the country's grey literature on the electricity and solar sectors (PROCEL/ Eletrobras, 2007: 18; Figure 5.10). On average, electric showers account for 18% of the country's peak demand. Every day between 6 and 7pm, as millions of Brazilians return home from work and take their daily shower, 42% of the country's electric showers are switched on (Governo Federal do Brasil, 2010b: 100). Like the director of the Brazilian Council for Sustainable Construction, various construction professionals interviewed consider the electric shower as being "culturally ingrained" in Brazil, part of the cultural practice of taking a shower after work and before dinner (Interview P37). In the view of a Brazilian advocate for renewable energy and former campaign director at Greenpeace, this daily practice of showering has significant implications for both the electricity sector and the environment:

> *The [electric shower] is efficient, because the objective of the product is to heat up water. So if you lose all the energy that you have for heating purposes, then that is okay. But efficiency is not a good measurement here…. the problem is consumption, in the amount of energy that is consumed, and at what time. Because if everybody is going to consume at the same time, that is going to give a very high peak. It is the issue of concentration, not efficiency…. the electric shower is one of the main problems we have for both the electricity sector as well as the environment (Interview P31).*

Private, non-profit and public sectors alike share this episteme around peak demand, as a way of problematising the country's electricity system. In line with the quote above, an energy efficiency manager at one of São Paulo's largest electricity providers pointed to the difficulties that the use of electric showers poses for utility companies. He highlights the role that electric showers play in the design and configuration of Brazil's electricity network, signalling the difficulties associated with managing the country's demand curve and its peak load:

> *The electric shower is the big villain of the national energy system, [and] it is a big villain for the utility company… because we have to design our entire system to serve 3 hours of the day… so it is very complicated. The peak load demand curve in Brazil is very complicated for the utility companies... And for the entire system, because here comes the distribution company, transmission, and generation, so it affects the entire electricity system. Therefore, our biggest problem really is the power load (Interview I19).*

In discussing the impact of the electric shower on the city's infrastructure, a former Planning Director of the State of São Paulo explained how historically the peak load generated by the electric shower has been the determining factor in establishing the size and capacity of São Paulo's energy distribution network (Interview D31). In the absence of a fully developed natural gas network for the city, the electric shower became a technology ingrained within the local planning system via São Paulo's Building Code (*Código de Obras de São Paulo*), fostering an urban development path that is highly electricity-dependent. Throughout the 1980s and 1990s, electric showers were mandatory in new construction. This provision was amended over time to allow also for gas systems, as the city's gas network was developed. This is criticised by renewable energy advocates who, until recent changes in legislation, saw these provisions as one of the main barriers for a more sustainable energy regime:

> *… the housing law, the law for building houses in the city, already creates in the building the need to make an investment in non-sustainable energies. One example is electric energy for water heating, which is completely absurd (Interview P31).*

The Brazilian electricity system is designed to cater for the needs of a basic domestic water-heating technology. Environmental advocates and sustainability experts complain that the government has to invest billions of dollars in hydroelectric and other power facilities to generate the energy required to operate electric showers. From their perspective, the use of resources associated with developing the infrastructure required by this domestic technology has significant fiscal and social implications, as these resources could be reallocated to health, education, or other social needs. As Section 5.4 further elaborates, the problematisation of showering practices and technologies leads to the adoption of SHW systems as an alternative strategy for energy provision. Scaling up SHW systems occurs through a key urban dynamic upholding a specific ethos: social housing provision.

5.3.3 Climate change narratives as local energy enablers

The emergence of a climate change agenda at the city level operates as the third rationality through which energy is problematised at the urban scale. Both Thane and São Paulo have been active in incorporating climate change discourses and initiatives into their policies and projects (Section 2.4). In both cities, climate change has operated as a policy discourse that provides a relevant context to the energy interventions and harnesses political support towards the continuity of experimentation with local energy infrastructures. This can be seen as an expression of the episteme of the regime. Climate change operates as a narrative that justifies, both nationally and internationally, local energy interventions. In doing so, it expands their reach and enables them to travel beyond the confined domains offered by narratives on financial savings by linking them with broader discourses on local and global sustainability and bridging local, national and global politics.

Thane: unpacking the relationship between climate change and energy in a context of financial austerity

In 2008, with the financial support of the British High Commission, ICLEI started the preparation of Thane's first GHG Emissions Inventory. The resulting report included an action plan with a list of measures aimed at emissions reduction; the majority of these were local energy initiatives (ICLEI, 2008c). By 2010, just as the emissions inventory was ending, the Indian Ministry of New and Renewable Energy announced the Solar Cities Programme. ICLEI saw an opportunity to continue the work originally laid out by the GHG Emissions Inventory, and contacted Thane to explore possibilities for maintaining their collaboration on the energy and climate change interface, but this time under the new programme. As a project officer at ICLEI put it, "the Solar Cities project is a continuation of what we had done under the British High Commission project… we thought 'let's continue the relationship through this'" (Interview P5).

Thane's joint work with ICLEI has provided the city with a platform to link climate change discourses and local energy agendas. This is reflected not only in initiatives aimed at generating a local impact – such as the Solar Cities Masterplan – but also through the city's involvement with the global sites where climate change agendas are being discussed. In particular, the working relationship between Thane and ICLEI led to an invitation to Thane's Municipal Commissioner to the 14th session of the Conference of the Parties to the UNFCCC in Poznań, Poland, in December 2008 (Figure 5.11). Speaking at the UNFCCC on behalf of local governments and municipal authorities, Thane's Municipal Commissioner set out a progressive energy vision for local governments, where the local level is in a position to lead on climate action thanks to its ability to redeploy energy infrastructures:

> *We have started to switch our communities into sustainable energy economies through energy savings. We apply renewable and high efficiency technologies to reduce dependency on fossil and nuclear fuels… we aim for lowest-carbon options. We are key in the design and the implementation of energy and infrastructure guidelines… If we are genuinely empowered and resourced, we have the potential to lead on climate action and can help to ensure that ambitious targets for the reduction of global greenhouse gas emissions are met.*
>
> *Nandkumar Jantre,*
> *Municipal Commissioner of Thane 2006-2010,*
> *Speech at the UNFCCC COP-14, December 2008*
> *(ICLEI, 2008b)*

Figure 5.11: Intervention of Thane's Municipal Commissioner, Nandkumar Jantre, at the 2008 UNFCCC's COP-14, Poland (ICLEI, 2008a).

However, in the case of Thane, climate change did not operate on its own as a mechanism capable of positioning a new local energy agenda. This is rarely the case, as identified by the early literature on cities and climate change, which points to the framing of climate change initiatives in terms of co-benefits (Betsill, 2001). Climate change, energy savings and financial opportunities for the municipal budget are entangled narratives in Thane's local governance of energy. When talking about Thane's motivations behind its extensive engagement with local energy initiatives, Nandkumar Jantre, the city's former Commissioner confirms that "climate change and carbon footprint was very much in our forefront" (Interview P9).

Yet the staff member in charge of the municipality's energy programmes points that issues of energy efficiency were part of the municipal agenda years before starting an engagement with climate change issues. In his view, in a municipality where up to 5% of the total annual budget is spent on electricity payments for municipal operations, incorporating a form of energy thinking within municipal practice is fundamental given its potential for reducing operational costs:

> *… global warming was not a priority in those days. I am talking about year back in 2000. There our priorities were that we could reduce our energy bill. If we reduce our energy bill this is one thing, second things is… a reduction in maintenance cost... Of course, later on we understood global warming and all these things. But global warming alone was not our focus, honestly speaking. So that was our focus, later on we started learning global warming and ozone layer depletion (Interview P11).*

Environmental discourses that optimistically emphasise the financial savings of environmental interventions sit within the realm of what is referred to as 'ecological modernisation', a view that focuses on the role of technology and institutional change in solving environmental problems whilst generating economic benefits (Hajer, 1995). It is a view that does not see environmental issues as contrary to growth, but rather as a means to safeguard growth via the "'selective incorporation of ecological goals in the greening of urban governance' both as a means of managing ecological dissent or pursuing new accumulation strategies (While et al., 2004: 551, 554)" (Hodson and Marvin, 2007: 306). In Thane, the prospect of financial savings aligns a variety of municipal stakeholders that do not ordinarily engage actively with issues of energy and resources, and plays a key role in consolidating energy related discourses and interventions into municipal actions. The search for economic benefits explains the adoption of energy efficiency as a guiding principle for municipal operations, but it does not account for the extension of this logic to the totality of the city. What explains this?

Through initiatives such as the Solar City Programme, the municipality has adopted a way of thinking about energy where financial benefits are not the primary driver, as the scope of the programme goes beyond energy usage in municipal operations and targets industrial, commercial and residential sectors. Climate change rationalities provided the required vocabularies, knowledges and viewpoints that transformed the debate around renewable energy and energy efficiency from an ingenious cost-saving device for municipal operations (where the municipality was interested in conducting its own energy conducts) to a desired citywide intervention (where the interest lies in conducting the conducts of others). Yet, even in this broader territory associated with a local governance of energy, financial logics traverse the city-climate change relationship through the promise of additional funds. In August 2011, ICLEI presented the final version of the Solar City Masterplan to Thane's Solar City Stakeholder Committee, chaired by the city's Municipal Commissioner, as part of the initial stages of implementation of the Solar City Programme (Section 7.3.2). Consequently, the Commissioner informally instructed ICLEI to start looking for mechanisms to translate the Thane Solar City Masterplan into CDM projects and applications and inquired about the possibility for obtaining CDM credits because of the city's 2005 decision to make the use of SHW mandatory. The energy-climate change axis operates as a discursive promise around funding income streams for local operations.

São Paulo: climate change framing energy policy initiatives

Between 2005 and 2012, under the leadership of two successive mayors from Brazil's Social Democratic Party, Jose Serra and Gilberto Kassab, São Paulo took an active role in developing urban responses to climate change (Section 2.4.3). São Paulo's GHG inventory was launched in 2005, during the mayoralty of Jose Serra (Prefeitura do Município do São Paulo, 2005). That same year the city instituted its 'Municipal Committee on Climate Change and Eco-economy', with the participation of staff members from the different municipal departments. The activities of this Committee would eventually lead to the city's Solar Law (launched in 2007) and its Climate Change Policy (CCP; *Lei 14.933, de 5 de Junho de 2009*), making São Paulo Brazil's first city to take such steps. Kassab, originally Serra's deputy, actively engaged with the C40 Climate Leadership Group and hosted the C40 Mayors Summit in 2011 (Figure 5.12). São Paulo's 2009 CCP was followed in 2011 by a Climate Change Action Plan (PACC) (Prefeitura do Município do São Paulo, 2011a), consolidating issues of climate change mitigation as an important local policy agenda. The PACC provides guidelines and priorities for future investment in the areas of transport, energy use, land use, building construction and waste resource management. These range from the development of mechanisms to ensure that all public transport vehicles run with clean and renewable technologies, to experimental initiatives to develop energy from waste.

After Jose Serra's early resignation from the mayoralty of São Paulo in 2006 and his successful bid to become the State's governor, similar climate change policies followed at the state level. In November 2009, the State of São Paulo launched its Climate Change Policy (*Política Estadual de Mudancas Climaticas - Lei 13798/09*), the first at the state level in Brazil. It was succeeded by the publication of the States' first Greenhouse Gas Emissions Inventory in 2011 (Governo do Estado de São Paulo, 2011). The policy commits to a 20% reduction of emissions by 2020, and calls for reducing the energy intensity of industrial processes within the state. The decision of São Paulo's CDHU, an organisation whose president responds directly to the State's governor via the Housing Department, to install SHW systems in the majority of its dwellings sits within this context. "We're thinking in a different way …always thinking about how not to generate carbon emissions", was the response from the energy efficiency manager of the CDHU when asked about how climate change issues influenced the solar programmes at the CDHU (Interview P26). Key staff implementing sustainability initiatives at the CDHU are aware of the mandate established by the State's Climate Change Policy and stress how the policy makes specific guidelines requiring the construction sector to address issues of sustainable energy and energy efficiency in buildings (Interview P25).

Figure 5.12: C40 Summit in São Paulo, in 2011. From left to right: Michael Bloomberg (Mayor of New York City), Bill Clinton (former President of the United States), Gilberto Kassab (Mayor of São Paulo) and Robert Zoellick (President of the World Bank) (Prefeitura do Município do São Paulo, 2011b).

Climate change as a local energy enabler

Climate change in Thane and São Paulo has been a framing logic that has enabled local energy discourses and initiatives to gain traction and travel beyond their exclusively local reach (Bulkeley and Betsill, 2003). Climate change rationalities, though techniques such as inventories, reports and policies, have functioned as stepping-stones for consolidating a local governance of energy, and in this sense are constitutive elements of its episteme. Its ethos is highly shaped by financial logics. Energy issues sit at the core of how both cities have attempted to respond to climate change, and the empirical material shows how energy and climate change agendas co-constitute each other at the local level. For both cities also, local engagements with climate change have also been to a large extent global and international outreach exercises (Bulkeley and Betsill, 2013; Bulkeley and Betsill, 2005), resulting in visibility at local and global levels. Thane's climate change discourses have been developed in the context of the city's engagement with the global governance of climate change, enacted by transnational organisations with knowledge and capabilities gained through international collaborations, and encased by the possibility of accessing additional funding streams such as the Clean Development Mechanism. Yet, in spite of a growing role for transnational networks in shaping India's climate change politics, research suggests that understanding this process requires being attentive to the spatiality of the policy process, particularly the role of local dynamics (Fisher, 2012). São Paulo's climate change agenda has supported the city's ambitions to position itself as a global economic player, whilst also providing a platform for the integration of a multiplicity of local agendas such as energy, building sustainability and housing provision. The urban governance of climate change and the emerging local governance of energy are entangled, through modes of governance that operate via a variety of stakeholders located at different scales, such as public and private non-profit and transnational sectors (Bulkeley and Betsill, 2013). In this context, solar objects emerge as a possible solution to climate change as well as various other urban problems.

5.4 The rise of local energy solutions and the consolidation of solar objects

The problematisation of energy in the city leads to a search for alternative ways of imagining local energy systems. The availability of sunlight in itself does not explain the consolidation of solar technologies. In Thane and São Paulo, SHW becomes an ideal candidate to solve the local energy problem for two reasons. First, the possibility to generate material efficiencies through interacting with local showering practices. This is examined through the experience of São Paulo's CDHU in promoting SHW systems in social housing. It highlights how the local governance of energy unlocks the energy of water at a local level, accomplished through reassembling and integrating urban infrastructures and drawing on the interface between different resources, specifically through the water-energy complex. In São Paulo, this reworking of the electricity-water-energy relationship leads to new forms of resource circulation, freeing electricity markets from the constraints imposed by peak demand consumption whilst also contributing to social agendas around housing provision.

Second, solar technologies establish a role in the city via their symbolic power and the non-energy uses associated with the visible imagery of solar technologies. This is examined through an analysis of the experience of Thane, where solar technologies provide a visual language and refreshed set of imaginaries in the service of urban growth agendas, reaffirming the city's commitment to innovation, autonomy and self-sufficiency in the midst of rapid growth and resource constraints.

Overall, the consolidation of the solar energy regime is the result of a change in episteme, which involves novel ways of thinking about, generating and delivering energy, establishing locally based and optimised mechanisms that contribute to a localised resource security. In line with how governmental rationalities operate, the ways of thinking about the energy problem carry the solution within themselves. The resulting solar energy regime redefines the relationship between nature and the city through a type of urban infrastructure that functions in tandem with the seasonal climatic variation of the city. This energy regime is highly attuned to local material conditions, acknowledges ecological cycles and works in tandem with the uncertainties embedded in the natural world.

5.4.1 Material power: the energy of water

The solar energy regime operates through a material reworking of the water-energy relationship, which enables a new series of efficiencies and optimisations that make it possible for solar technologies to appear as an attractive option for energy interventions. As Chapter 2 illustrated, water and energy have had a long and intertwined history of working together within the worlds of electric power. Yet, as people switch the lights on, the water-energy relationship often passes unacknowledged. Water, in both its liquid and gaseous form, is used to power electricity generation equipment. Besides the obvious resource connection involved in hydroelectricity, thermal power plants use coal to convert water into steam for generation purposes. The Director of Thane's Electric Engineering Department expressed how, after heating water to colossal temperatures solely to generate electricity, using that electricity again to heat up water is not without a tone of irony. After campaigning for the city's Solar Law, he argued that using electricity for heating water is "as good as using a machine gun for killing a mosquito!" (Interview P11). Like him, a member of the team that drafted São Paulo's Solar Law points to the pitfalls of using electricity for such purposes, arguing that the use of SHW could result in redirecting electricity "for something that is more important, such as a computer, the Metro [or] electric buses… It gives us a better use of energy" (Interview P21). Challenging the use of electricity for heating water involves a new way of thinking about the water-energy nexus, alongside a new ethos around what electricity is for. It also involves unpacking such nexus not only in the engineered and centralised spaces of energy generation (e.g. hydroelectric plants), but also in social-technical and decentralised spaces in close proximity to the points of consumption.

A broad range of small scale renewable and energy efficiency interventions rely on a more explicit acknowledgement of the water-energy relationship. In Thane, for example, water is used as energy storage for increasing the energy efficiency of the city's main public auditorium. Steam generated through solar parabolas is used in a heat-exchange system for cooling the air of the city's largest public hospital (Figure 5.4). As part of the same system, the water content of the air of the hospital (in the form of humidity) is reduced in order to lower the energy input required in the cooling process, in effect making the solar investment viable. Finally, the second highest energy savings in municipal operations, after the implementation of energy efficient street lighting, came from interventions in the city's water distribution network (Thane Municipal Corporation, 2010). In both Thane and São Paulo, SHW for residential purposes provides another example of the local use of water for energy purposes. The remaining of this section examines this integration of resources is examined in greater detail, focusing on the experience of São Paulo's CDHU and their interaction with private electricity providers for the replacement of electric showers with SHW.

São Paulo's social housing and the replacement of electric showers with SHW

In the State of São Paulo, the acknowledgement of energy efficiency as an entry point to a sustainability agenda has led to a partnership between the CDHU and the region's private electricity providers. With national legislation requiring utility providers to invest in energy efficiency in low-income population, a reworking of the water-energy interface through SHW systems to replace electricity use for showering purposes emerged as a solution for the problems of the electricity grid, simultaneously contributing to a social agenda of housing provision. Since the late 1990s and early 2000s, the ANEEL has campaigned for energy efficiency and a long-term reduction in electricity use. In 2000, ANEEL pushed for regulations requiring private energy utility companies to spend 1% of their net income on energy conservation (*Lei 9.991, de 24 de Julho de 2000*). Such investments are highly regulated, covering energy efficiency (50% of the funds) and research & development (20% of the funds), amongst other topics. Since 2010, the pro-poor policies of President Lula have required 60% of the energy efficiency funds to be invested amongst low-income customers (*Lei 12.212, de 1 de Dezembro de 2010*).

These national level legislations brought about two particular problematisations of energy, emphasising issues of efficiency coupled with poverty alleviation. The combination of legally binding investments in energy efficiency for the poor and an electricity system constrained by the peak demand curve generated by the electric shower (Section 5.3.2) have made the use of SHW in social housing into an attractive option for utility companies. After negotiations between the CDHU and the largest energy providers in the State of São Paulo – EDP Bandeirantes, the Companhia Paulista de Força e Luz and AES Eletropaulo – a series of agreements were signed for the donation of SHW systems to social housing. In line with the deployment of an ethos that incorporates the user within the conception of the energy regime, these agreements were not limited to the provision and maintenance of SHW equipment, but also included user training and energy awareness activities (Figures 5.13 and 5.14).

By replacing electric showers, SHW therefore was seen to provide a solution to many of Brazil's electricity problems. The key electricity benefit provided by SHW is not a reduction in the total annual energy requirement of the population (also known as consumption), but a specific reduction in the amount of power required at specific moments in time (known as demand, power, or the immediate rate of consumption). This is of particular significance during peak demand periods. This is articulated by the energy efficiency manager of one of the largest electricity providers of São Paulo, who argues that "from the point of view of energy efficiency for the utility company, the biggest benefit [of the SHW system] is the power; it is the reduction of demand during peak hour" (Interview

Figure 5.13: Energy awareness activities organised by AES Eletropaulo in Tiradentes, São Paulo, as part of a program for the donation of SHW systems in social housing.

Figure 5.14: Children learning about SHW systems in Tiradentes, São Paulo.

Figure 5.15: Neighbourhood party in Tiradentes, São Paulo, as part of a program for the donation of SHW systems in social housing.

I19). This enables distribution utility companies to have greater flexibility in their electricity sourcing strategies. It also frees up financial resources within the sector, originally earmarked for the expansion of electricity generation, transmission and distribution and required in order to cope with peak demand moments in the context of a limited supply. In light of this, the electricity sector is a keen promoter of SHW use.

For the CDHU, the acknowledgment of the contribution of SHW to overcoming the limitations of the country's electricity grid played an important role in harnessing the required political will within the CDHU for the widespread adoption of this technology. The energy efficiency manager of the CDHU, a high-level staff member with direct access to the company's president, explains that:

> *… from the perspective of the overall electrification system, we would manage to reduce the demand of the electric shower during peak hour. It is from that point of view that the political will emerged, underpinned by those real factors… The political will to move ahead with SHW for low-income housing (Interview P26).*

As of 2011, these partnerships had resulted in over 16,000 SHW systems installed, with thousands more in the pipeline. The use of SHW systems donated by utility companies is limited to existing buildings, as ANEEL requires a proven reduction of existing energy consumption in order to justify the investment in energy efficiency (ANEEL, 2008). Detailed measurements of electricity consumption before and after the installation of SHW systems are carried out by energy consultants paid for by the utility company. The large majority of installations have occurred in detached single-family homes (horizontal development) outside the city of São Paulo, in less urbanised areas in the periphery of the State. However, in 2012, installation of 5,000 additional SHW began in low-rise social housing towers in Tiradentes (vertical development), a popular neighbourhood on the east of the city of São Paulo (Figures 5.13 to 5.15). Staff members of the CDHU expressed how the widespread use of SHW systems in social housing in the city of São Paulo is likely to increase the visibility of SHW as an energy strategy with national significance, given the political clout that projects in the city carry with respect to the national and regional political context. This is also likely to provide new technical insights and valuable publicity to legitimise the intervention:

> *The plan is to install 5,000 SHW systems in the city of Tiradentes … inside the city of São Paulo. That is going to have an impact, both political and technical. Everything that you do in the city of São Paulo gains greater visibility… the more people aware of how the CDHU is shifting towards a policy of sustainability, the better… Then the visibility is something that is important (Interview P25).*

Yet this visibility not only enables a widespread adoption of SHW systems in the city, but it also modifies energy markets in the city. SHW systems perform an important function by freeing the energy market from the constraints imposed by the daily peak electricity demand, opening up new opportunities for the circulation and marketisation of energy. The material water-city-energy interface plays a key role in enabling or limiting this experimentation with SHW. Despite the creation of new marketisation opportunities, the resulting energy circulations draw upon an ethos that enacts social logics through a sustainability intervention that supports issues of social justice and poverty alleviation through social housing (examined in detail in Chapter 7).

5.4.2 Symbolic power: eco-technical imaginaries fuelling local agendas

Solar technologies speak of the future. The solar energy regime draws on a particular telos that portrays an ideal eco-modern society. Solar technologies provide powerful utopian imaginaries about efficiency, optimisation, cleanliness and innovation (Maassen, 2011). Beyond their purely material power, their symbolic power mobilises a set of eco-technical imaginaries destined to serve diverse urban agendas. Several of the dimensions established within an analytics of governmentality are present in the ways by which this 'solar' way of thinking about the city (the episteme), underpinned by visual and technical vocabularies (visibility), produces a truth about the future (the telos): eco-friendly, sustainable, autonomous and, above all, with enlarged capacity – electric capacity, resource capacity and growth capacity. This moral form of 'the solar city' (and its growth ethos, a strategic narrative endowing the intervention with an overall coherence) is examined here by analysing the relationship between Thane's solar initiatives, the Solar Cities Programme, and the city's real estate dynamics.

Futuristic views of the city: the imaginaries behind India's Solar Cities Programme

As part of ICLEI's commission for the preparation of Thane's Solar City Masterplan, a generic *Guidebook for Developing a 'Solar-City'* was developed: a non-site specific guide aimed at introducing the notion of 'solar cities', describing the portfolio of technologies that make it up and providing a set of generic financing and implementation tools (ICLEI-SA, 2010b). The guidelines present a vision for a 'solar city' inspired by international initiatives and exemplars. These range from transnational city networks – such as the European Green Cities Network, the Energie Cities Association and the International Solar Cities Initiative –, to world-renowned examples of solar cities – such as Freiburg, Barcelona and Linz. The document locates the 'solar city' in the realm of the future: "Lots of new research and development in this field has opened an array of ideas for futuristic yet sustainable cities", reads the guidebook as it introduces a set of abstract futuristic architectural images portraying solar-based street furniture (Figure 5.16) (ICLEI-SA, 2010b: cover).

Figure 5.16: Futuristic images portraying solar street furniture, (included in Thane's Solar City Masterplan - Guidebook) (ICLEI, 2010b: cover).

Such futuristic visions emphasise the fulfillment of urban functions through solar technologies. Solar panels sit on the roofs of commercial and residential buildings, power bus stops, phone booths and ATMs, and serve as urban landmarks (such as the Barcelona Solar Pergola). The images act as strong visual references pointing to a technological future. Behind this futuristic and technological vision, there is a dream of self-sufficiency as a mechanism to bypass the current failure in infrastructure provision, and as a response to the need to increase resource security at the local level. This ideal of self-sufficiency and resilience is enshrined in Thane's City Development Plan, which states that the Municipal Corporation "has an ambitious plan of achieving self-sufficiency in power requirement" (Thane Municipal Corporation, 2006: 75). It is a vision of autonomous infrastructures that bypass the failing centralised provision and extend to a variety of urban energy services, from electricity for domestic uses to traffic lights. Embracing this vision, the Director of India's Solar Cities Programme explained in Delhi how the initiative is "planning to have every house [as] its own powered house" (Interview P1).

By the time the Thane Municipal Corporation joined the Solar Cities Programme, the city's previous energy projects had already engendered a national reputation as a hub for energy innovation. The solar air conditioning system in Thane's main public hospital (Figure 5.4), the first to be installed in India, sparked dozens of headlines in the national press with titles such as *Thane civic hospital, a pilot for the future* (The Indian Express, 2008), *Can Thane go totally solar?* (Times of India, 2008a), *UN applauds Thane municipal corporation's green thumb* (Times of India, 2008b) and *Thane's planned solar energy project way ahead of its time* (Times of India, 2009). Over the course of the 2000s, Thane gained national visibility as a modern, efficient and forward-thinking local authority through its innovative energy projects and solar power strategies. In the past decade, the city has received several awards associated with its energy initiatives. This includes the prize for *Excellence in Energy Conservation & Management* awarded by the Maharashtra Energy Development Authority, obtained 6 years in a row between 2003 and 2010, and the *National Award for Energy Conservation* in 2005. In Thane, solar technologies have provided the city with national visibility, portraying it as a city that is actively involved in shaping its own future.

Ecological imaginaries underpinning urban growth

In the context of unpacking a governmental rationality around resource constraints, earlier this chapter discussed how growth in Thane has been conceptualised (and problematised) in energy terms (Section 5.3.1). Here the thesis discusses how solar technologies emerge in this context, shaping the resulting solar energy regime through forms of visibility and embedded with a telos around eco-modernities. The symbols and imaginaries associated with the notion of a 'solar city' are mobilised and reassembled to support specific local agendas, particularly urban growth.

Thane has experienced rapid and continued growth since the 1980s. In 2011, the Indian Census declared Thane District, where the city of Thane is located, as the most populated in the country (Government of India, 2011). In 1981, the city of Thane had a population of 475,000. By 2011, this population grew almost fourfold to 1,820,000. Thane's recent annual population growth rates triple those of greater Mumbai. Population growth has fueled a real estate boom, and over the past years the city has converted significant amounts of industrial land for residential purposes. Most of this growth takes the form of luxury residential towers in the northern outskirts of the city, aimed at the middle and middle-upper classes, making the real estate sector one of the most influential political forces in local politics (Figures 5.17 and 5.18). Residential developments aimed at a new consuming middle class sit side by side with shopping malls catering to their newfound purchasing power. As the City Development Plan explains, "people in the city with disposable income and an escalating propensity to spend has prompted the development of organised retail market in Thane" (Thane Municipal Corporation, 2006: 48).

Figures 5.17 and 5.18: Thane's urban growth areas.

In May 2011, Thane celebrated its 11th Real Estate and Housing Finance Expo. This is an annual real estate event organised by the municipality, along with the Maharashtra Chamber of Housing Industry (a construction and real estate development business association). This year, exhibition panels prepared by the municipality proclaimed Thane as "India's 1st Solar City" (Figure 5.19). Gigantic screens rolling promotional videos of Thane stood next to a $40m^2$ physical model of the city. This 'Thane Vision 2020' portrayed the city as the most upcoming Tier II city in India,[12] and a 'futuristic city' characterised by quality of life, cultural activities, connectivity and innovative industries (Figure 5.20). The exhibition panels presented a future vision made up of world-class transport infrastructure, skywalks, monorails, bridges and flyovers. Amongst these, photos of the municipality's building roof terraces and its solar photovoltaic system evoked the city's achievements with pilot energy initiatives. India's first solar air conditioned plant – backed by the Solar Law requiring all new construction to install SHW systems – joined the proposed international convention centres, stadium and sports complex, planetarium, libraries, and science parks that form the modernisation narrative of the city, its ambition for the future and its discourse to attract the emerging middle classes of Mumbai and Maharashtra. The video running in the background drew on eco-technical narratives to portray Thane, "home to over 18 lakh [1.8 million] upwardly mobile citizens", as a place

> *where environment and man-made advancements coexist complementing each other… A growing city surrounded by a creek… Thane has set and enviable benchmark in striking a perfect eco-balance.*
>
> *Thane Municipal Corporation*
> *Transcript of the video 'Evolving Thane'*
> *11th Real Estate and Housing Finance Expo, 1 May 2011*

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[12] National classification on the basis of population.

Figure 5.19: Thane's 11th Real Estate and Housing Finance Expo. Exhibition billboard celebrating Thane as 'India's 1st Solar City'.

Figure 5.20: Thane's 11th Real Estate and Housing Finance Expo.

Solar imagery plays an important role in backing the city's claims to eco-balance and quality of life. In the midst of rapid urban growth and an increase in resource demand, the municipality has developed a discourse that reconciles growth and environmental stewardship. "That is why it becomes all the more necessary to promote the energy conservation, and promote [the] use of alternative sources of energy like solar energy" responded a former Municipal Commissioner of Thane, in office during the early days of the Solar Law, when asked about the tensions between the city's characteristic rapid urban growth and energy consumption:

> *So it is all the more necessary because of the growing energy demand… so solar energy and energy conservation has to be there to meet the growing demand of energy from a growing and prospering population. There is more employment, more prosperity, more money, more population growth, more energy demands, more ACs, more lifts, more malls and more commercials, more energy consumption. So it is all the more necessary that whatever energy you are having we practice energy conservation to the fullest extent and there is no end to it and we can go to any extent by promoting continuously and we must promote the use particularly of solar energy (Interview P9).*

The seductive appeal of solar technologies and their visibility as symbols of progress and modernity is mobilised to serve the agenda of urban growth. Through highly visible objects charged with symbolic meanings, solar objects become a "technolog[y] of representation and the [tool for the] execution of a political imaginary" (Legg, 2007b: 11). The visual qualities of solar systems and photovoltaics, on exhibition boards (Figure 5.19) as much as in spaces of growth (Figure 6.21), reassure locals and non-locals of the city's commitment to 'clean growth' and 'first-class' infrastructure. In this way, the solar energy regime draws on visual vocabularies that portray the local government as innovative, forward thinking, budget-cautious, responsible and environmentally conscious, playing an active role in shaping its future.

5.4.3 SHW systems: redefining the relationship between nature and the city

A resulting characteristic of the resulting local energy regime is a reconfiguration of the relationship between city and nature. This points towards a further transformation of the episteme of the energy regime, and in this way opens possibilities for a different way of thinking about energy in the city. The widespread use of SHW puts in place a type of urban infrastructure that explicitly recognises and incorporates the seasonality of the city, its geophysical conditions, and its natural variations. This redefines the relationship between nature and the city by enabling a type of urban infrastructure that takes account of natural cycles and responds to them. For SHW to be useful, and to have agency within the city's electricity system, an alignment of a variety of socio-geophysical conditions is required, including solar insulation, cloud coverage, latitude, longitude and altitude (for the arrangement and orientation of the collectors), temperature, humidity, seasonal cycles and even local customs about the everyday use of water. It is a form of infrastructure that is highly attuned to the conditions of the locality, and in this way defines a different way of relating energy and territory.

Beyond (sun)light: the visual 'geophysicality' of solar energy

The extensive availability of the sun as an 'unlimited and untapped resource' is a widely cited justification for the roll out of solar technologies in the city. For example, when justifying the Solar Cities Programme, its Director explains that "India has a lot of sunshine… we have more than 300 days of good sunshine [per year], so why not use it?" (Interview P1). In Brazil, DASOL claims in its promotional material that the country's solar potential is in the order of 15 million MWh, or "50,000 times the national electricity consumption" (Figure 5.21; Mesquita, 2010: 8). The geographies of solar potential, through coloured national maps displaying the levels of intensity and potential availability, operate as visual techniques mobilised to convince local governments, users, or international agencies, amongst others, of the power possibilities of the sun in national and local landscapes (Figures 5.21 and 5.22).

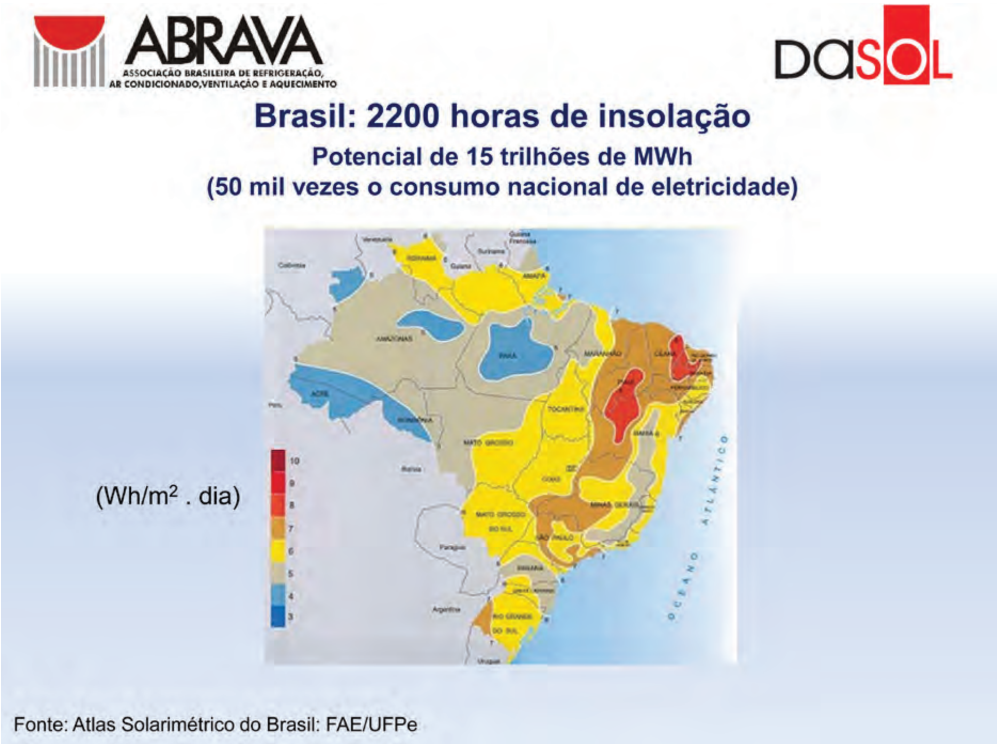

Figure 5.21: Map of solar insolation, Brazil (as part of DASOL's promotional material) (Mesquita, 2010: 8).

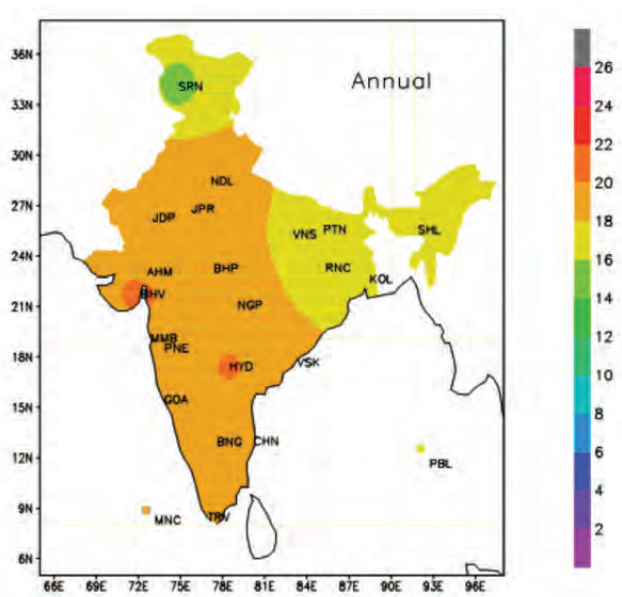

Figure 5.22: Map of solar insolation, India (included in Thane's Solar City Masterplan - Guidebook) (ICLEI, 2010b: 11).

Geographically, both São Paulo and Thane are well positioned to exploit this potential, with an average annual insolation of 16 MJ/m^2/day and 18.2 MJ/m^2/day respectively (Tiba, 2000: 59; ICLEI, 2011: 40).[13] In Thane, where 3 seasons structure everyday life (summer, monsoon and winter), the SHW system is useful for 6 to 8 months of the year. During winter, from November to February, the mornings are cold but the days often sunny, making SHW an ideal system for heating water for the morning bath. As the city moves from winter to summer, higher temperatures render SHW systems useless for a number of users who find the climate too hot and humid for a hot water bath. This is the result of a combination of the tropical latitude and the high water content of the air resulting from Thane's location along India's western coast. In the Mumbai Metropolitan Region, in contrast to other cities located at similar latitudes but away from a coastal location, "humidity means, you'll see, sweat. When a person is sweating you'll not feel like taking [a] hot water [bath]", explains a representative of a manufacturer of SHW systems (Interview D15). After the summer is over, Thane experiences the monsoon: 3 to 4 months of torrential rains where the acute cloud cover affects the performance of SHW systems. As a user, who is also an aficionado of solar technologies (Figure 5.23), explains:

> *…in winter is sufficient, [but] in monsoon is not sufficient. So in monsoon for many days we don't get hot water. Because if it is very cloudy, of course you don't get; if it is rainy you don't get. But if it is cloudy, then you get a little hot water. And if you accumulate it for two days, then you get [hot water] for one day (Interview U1).*

São Paulo shares with Thane the experience of sunny winters. However, with only two seasons and without a monsoon, the use of SHW is well suited. Like in Thane, several interviewees commented that the use of hot water for

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[13] Thane's data has been converted to MJ from 5.08 kWh. For comparison purposes, Central Australia's insolation of 21.2 MJ/m^2/day is considered very high whilst Dublin's 9.2 MJ/m^2/day are considered moderate.

Figure 5.23: SHW user describing a system at his home in Thane.

showering was seasonal. "Very often during the summer you don't need to use the electric shower. In winter, it is a requirement. Otherwise, we don't take a shower... because it is cold" (Interview U20), explained one non-SHW user. Those who use SHW systems find them more useful during the winter, from May to October, when a monthly rainfall average of 66mm (compared to 178mm during the summer) means that despite the cold weather there is enough solar radiation to feed the SHW systems. One promoter and user of DIY SHW in São Paulo summarises his seasonal use of SHW and his positive experience with the system (Figure 5.24) as follows:

Until today, it has been only happiness. Particularly during the winter, when you would have to use the electric shower of 6 or 7 kW, which in principle is a very high consumption… with the solar [system], during winter there is sun... Not during summer. During the summer you have some sun in the mornings, but in the afternoon it rains. In winter you have sun the entire day, so it heats up more (Interview P36).

Given the seasonal climate and daily weather variations, government agencies recommend the use of SHW alongside another form of water heating to act as a back-up (MNRE, 2010). By 2009, the Brazilian government estimated there were over 5.2 million of m^2 of installed SHW collectors in the country, equivalent to CO_2 savings of 86,000 tCO_2. The collector area is expected to reach 15 million of m^2 by 2025 (Governo Federal do Brasil, 2010b). In India, despite an estimated potential of 45 million m^2 of collector area, only 2.5 million m^2 have been installed (MNRE, 2010).

Figure 5.24: User and promoter of DIY SHW describing the system at his home in São Paulo.

SHW: integrating resources and acknowledging natural cycles

The rollout of SHW in Thane and São Paulo speaks of an emerging mode of urban infrastructure that purposefully and openly acknowledges connections and circulations with nature – a new episteme around energy. The solar energy regime is underpinned by an acknowledgement of natural cycles, and their incorporation within the city's system of energy provision. A cloudy day means that the following morning there will be no hot water, and the back-up electric (or gas) shower or boiler will be used to makeup for the shortcoming. The local governance of energy must recognise a multiplicity of geographical parameters and raises questions about the possible forms of infrastructural mediation between nature and the city. Here the sun needs to interact with other key resources, such as water, in order to attain agency. This is achieved by making different resources work together. SHW operates as an energy infrastructure highly defined by local environmental conditions. By design, the resulting energy regime needs to accommodate uncertainty and deal with risk and contingency, as made clear by the SHW manuals developed by the Indian government:

> *…solar water heating is done by the energy received from the Sun. If the energy input is reduced or cut off by clouds the heating of water is reduced… the hot water heated on previous day, is used in the morning of the next day. It will be known by the evening if heating during the day has not taken place, and auxiliary heating can be switched on for heating in the night* (MNRE 2010: 46)

This opens opportunities for a shift in how nature is perceived, defined and approached within urban infrastructures. This shift creates a type of infrastructure that both incorporates and responds to location-specific geographical and environmental conditions, such as solar incidence, rain patterns, seasons and other natural cycles. As such, it promotes a networked infrastructure model related not to a modernity that tries to overpower nature, but to an 'eco-modernity' that attempts to act in tandem with it.

5.5 Conclusions

Examining the ways in which urban energy has been problematised in Thane and São Paulo, the research found that three rationalities are involved: resource constraints, the emergence of climate change agendas in the city, and the problematisation of energy demand. These represent three different entry points leading to the creation of energy as an object in need of being governed locally, and through this the emergence of a solar energy regime – an energy regime that is more deeply connected to and embedded in the locale. In this process, local domains, from the city to the dwelling and the bathroom, are seen as key entry points for the reconfiguration of energy networks. SHW comes to the forefront as a possible solution, representing a technology that is highly attuned with local (climatic, social and urban) conditions. Yet, whilst the required acknowledgement of natural cycles and uncertainties within solar infrastructures make them seemingly appear in opposition to a modernity where technology is meant to overpower nature (see Loon and Beck, 2011), the resulting energy regime – through its unlimited solar resource ¬– contains elements of a techno-polis in which urban development can happen regardless of resource limitations.

In the case of India and Brazil, the problematisation of energy in the city is not exclusively an urban phenomenon, as the national level is deeply involved in this process. The rationalities examined show how the urban problematisation of energy comes first from an analysis of energy dynamics at national levels. From there, it moves to the city as urban practices such as high energy demand and urban growth are problematised. The city becomes regarded as a key space for intervention and an appropriate spatial and governance structure to realise the required change. In Brazil, the traditional use of electric showers is questioned as this domestic techno-cultural practice, and its daily temporalities, places significantly high demands on the national electricity grid in the form of daily peak demand loads. In India, the increased electricity demands of a rapidly urbanising nation and the growing gap between demand and supply lead to re-thinking the means by which growing energy needs can be supplied in cities. This marks a shift in traditional understandings of energy security, moving from national to local domains and from an emphasis on issues of supply to issues of demand.

Yet, unpacking the problematisation process also shows how agents at the local level are not passive recipients, but active stakeholders that embrace the energy problem as an opportunity for responding to a variety of – non-energy related – local agendas. Rolling out the local governance of energy through solar technologies carries a power beyond that of electricity, developing a new geography of energy for the city. Through the climate change and renewable energy interface, Thane and São Paulo developed a governance model that allows them to integrate different urban priorities into an integrated package (the energy regime), and to mobilise discourses that enable access to national and international financial resources. The agency of SHW systems within both cities' emerging energy regimes results from their ability to intervene in two domains. First, in the material domain, through efficiencies and optimisations achieved via the integration of resources, particularly energy and water. Here, water becomes an enabler/disabler of energy interventions, in a new mode of urban infrastructure that functions through resource integration. Second, in the symbolic domain, bringing on board additional resources and inputs for the advancement of pre-existing local agendas. For example, in Thane a discourse around 'the solar city' and its dominant technology, the SHW system, emerges as the bearer of a new eco-modernity that legitimises claims around a balance between human and natural worlds. As such, through telos and visibility, this local governance of energy embeds a symbolic power that is mobilised towards a multiplicity of objectives, beyond just keeping the lights on.

Thus, in Thane SHW is mobilised towards urban growth whilst in São Paulo it becomes a key input for the advancement of social agendas around housing and the universalisation of energy services. This reveals two modes of urbanism in relation to resources, underpinned by two contrasting urban agendas – the ethos of the respective local governance of energy. One, in Thane, where resources and local infrastructures operate as a key input for growth, and one, in São Paulo, where they operate as an essential mechanism for redistribution.

To understand the emergence of the local governance of energy it is necessary to excavate the rationalities that underpin it: the discursive mechanisms that compose it, the multiple viewpoints and sites from which it emerges, and the logics and forms by which it is enacted on the ground. When used in a comparative way, this approach reveals how seemingly similar global processes have very different local expressions. Despite the apparent similarity of how climate change, resource constraints and demand growth are shaping energy agendas in cities worldwide, the contrasting experience of Thane and São Paulo highlights the need to retain local specificity in energy research.

Chapter 6

Governmental techniques: the dispersed workings of the solar energy regime

6.1 Introduction

The solar energy regime and the use of SHW bring about a new way of constituting energy in the city. In contrast to centralised modes of energy production characteristic of the 20th century (Section 2.2), energy is produced with a high level of involvement of local governments and other state agencies that possess a strong local remit (Chapter 5). Yet, governing energy conducts in the solar energy regime is not the exclusive domain of the state. Local energy governance is conducted by and through fragile and dispersed agencies outside the direct control of centrally established nodes of power. In Thane and São Paulo, agency in the solar energy regime lies in the hands of a variety of urban stakeholders and small socio-material agents. This ranges from a handful of NGOs and government agencies promoting the use of decentralised energy technologies to a legion of independent and dispersed agents involved in the delivery and use of solar hot water, along with the materials that make this possible.

Drawing on Li's notion of 'assemblage' (Li, 2007a) and Dean's (2010) and Legg's (2007b) 'governmental techniques', this chapter illustrates the workings of the solar energy regime. In contrast with the previous chapter, prominence is given to the non-state agents involved. The focus is on the 'hows' of government, detailing the workings and failures of the specific mechanisms associated with the activity of governing: the routinised and seemingly coherent practices that make up the solar energy regime (Dean 2010). The emphasis of the chapter is the techne of government. The solar transformation of urban energy infrastructures in São Paulo and Thane relies highly on two types of governmental techniques: calculation and standardization. It is through these that a 'will to improve' (Li, 2007b; Section 3.3.2) appears on stage, is rendered possible, becomes re-appropriated, encounters resistance or achieves success. Scaling up SHW systems also relies on forging particular types of socio-material alignments (Li, 2007a). However, the analysis of the operationalisation of the solar energy regime presented in this chapter also draws on the governmentality dimensions examined in the previous: episteme, telos, ethos and visibility. Governmental techniques embed ways of thinking, forms of knowing and vocabularies (episteme and telos); execute principles that provide orientation and values (ethos); and draw upon forms of seeing and representing (visibility). Here a problem largely framed by electricity shortages (Chapter 5) finds a solution within a different set of sociomaterialities: water circulation and knowledge around domestic plumbing.

The operations of the solar energy regime do not rely exclusively on governmental modes of power, illustrating how different modes of power operate in tandem. Sovereign and disciplinary techniques (Section 3.3.1), represented by local laws mandating the use of SHW, are also mobilised. The contrasting stories of Thane and São Paulo show how the level of success of the solar energy regime is closely linked with the way governmental techniques are deployed and how they confront failure. The fragility of the regime, and the extent to which its orientation and mandates are prone to contestation and failure (Barry, 2001: 15), point to how the solar energy regime is not a consolidated project characterised by control and stability. Forging the required alignments involves the hard work and multiple (Li, 2007b). In practice, the regime operates as a contingent assemblage.

This chapter illustrates how the analytics of governmentality provides multiple entry points for an analysis of energy. In doing so, it contributes to the development of an energy geography that meaningfully engages with the material dimensions of energy generation. This energy geography also draws on an understanding of the interface between energy and other resources such as water, alongside a set of questions around resource circulations already familiar to scholars working on the analysis of urban infrastructures (Section 3.2). The work is deeply anchored within social science, recognising that the material and social worlds of energy are co-constitutive of each other. The chapter also opens possibilities for engaging with energy policy in ways that simultaneously evaluate the logics behind policy formulation and the mechanisms and material results associated with implementation.

The chapter is divided into five sections. Following this introduction, Section 6.2 provides a brief conceptual account of calculation and standardization as governmental techniques. It also examines the process of forging alignments and dealing with failures, and the various overlapping forms of power within governmentality. Each of the remaining sections is informed by one specific way of assembling as part of enacting a 'will to improve' energy in the city. Section 6.3 is dedicated to the rollout of governmental techniques. Section 6.4 focuses on the mechanisms for forging alignments on the energy-water interface. Finally, Section 6.5 is dedicated to the need to confront failure, particularly in the context of the coercive power of solar laws.

6.2 Constituting the regime: coercive power, governmental techniques, alignments and failures

In the low carbon energy transition, a new energy regime is constituted through the combined work of human and non-human agents scattered across the city. The result is a dispersed practice of energy production. This regime is deployed not only through the coercive power of the law, but also through forging socio-material alignments and rolling out governmental techniques.

6.2.1 Overlapping forms of power: the coercive power of solar laws

The emerging solar energy regime is not exclusively a governmental intervention, but one where different forms of power come together. In response to the problematisation of energy in the city (Chapter 5), both São Paulo and Thane have created local byelaws mandating the use of SHW systems in new buildings (Section 4.3.1). In this way, they use the constrained and targeted nature of the local planning system to discipline energy in the city. Solar laws do not solely fit within a governmental effort. They are also an example of sovereign and disciplinary powers at play (Foucault, 2009: 102), drawing on the absolute authority of the sovereign and operating through the violence associated with the threat of punishment (Rutherford, 2007: 293; Murray Li, 2007: 16). In contrast to governmental techniques, solar laws do not operate through freedom but impose a will over a defined territory (Legg, 2007b: 4). They do not 'enable', a defining characteristic of governmental power, but 'prohibit' (the construction of buildings without solar power), focusing on what one must do as opposed to what is forbidden (Legg, 2007b: 8). Yet such sovereign powers do not act alone. The solar law illustrates how different forms of power (Section 3.3.1) operate in tandem, and how within governmentality other forms of power – such as sovereign and disciplinary – are reformed to operate within the concern for the population and its optimization (Rutherford, 2007: 293; Legg, 2007b: 7; Foucault, 2009: 107).

6.2.2 Rendering technical: the governmental techniques of the local governance of energy

Governmental techniques operate as a series of powerful and connected yet mundane events aimed at consolidating SHW as a new form of local energy. In contrast to sovereign and disciplinary power, governmental power in the solar regime, rather than subjecting by the sheer power of the law, relies on mobilising the agency of the governed through the realm of freedom. This mobilisation is achieved via governmental techniques, which inevitably, embody the rationalities involved in the local problematisation of energy, thus enabling their deployment (Miller and Rose, 2008: 63). In doing this, they render the urban energy problem technical (Li, 2007a). Together, techniques and rationalities play a role in creating the object of governing.

Two governmental techniques play a key role in the constitution of Thane and São Paulo's solar energy regimes: techniques of calculation and standards. Dean (2010: 197) refers to these as techniques of performance. They are seen as tools for comparing, measuring and optimising, and in this way advancing rational ways of thinking and "penetrat[ing] the enclosures of expertise" towards the formation of new calculative regimes. They operate as instruments for intervention through a deployment of systems for measuring and representing data. They are also ways of thinking (forms of episteme), acquiring knowledge and framing reality. Such techniques of performance define access points, enabling certain agents to mobilise the governing effort towards their own interest (Dean, 2010). They can also be seen as the procedures that align the materials and forces in question towards the governing effort (Legg, 2007: 12), making the local governance of energy possible.

The local application of specific modes of calculation – baselines, masterplans and targets – allows local authorities invoved in the rollout of local energy initiatives to account for their energy consumption and that of those who live and work within the locality: who spends it, where, and how much. Through such accountancy mechanisms these governmental techniques render energy visible at the city level, constructing the field of intervention and enabling possibilities for acting in the future. Calculation techniques play an important role in making energy discernible, and in this way, creating 'local energy'. Objects such as a baseline and a masterplan "make it possible to 'picture' who and what is to be governed, how relations of authority and obedience are constituted in space, how different locales and agents are to be connected with one another, what problems are to be solved and what objectives are to be sought" (Dean, 2010: 41). In this process, energy 'in the city' appears visible, pointing to how "energy is effectively constituted by the means through which it is known" (Guy and Shove, 2000: 40).

The second governmental technique analysed in this chapter is the codification of material relationships and technical knowledge about solar energy into standards. Standards, alongside control systems and performance indicators, monitor the various human and material agencies at play (Dean, 2010). Standards make information comparable across locations, enable connectivity and regulate quality. These three characteristics of standards develop, respectively, what Barry (2006) refers to as metrological zones, infrastructural zones and zones of qualification. This process highlights the material nature of the governance of energy: a consciousness of the quality of materials as conductors or conservers of energy; of the paths of least resistance for energy flows; of the right angles of interaction between materials, and so on. Such knowledge is consolidated into quality standards, certification mechanisms and codes of professional practice, amongst others. By invoking particular forms of 'technical' truth, they regulate and assign implicit rights within an emerging local energy market (Section 6.3.2). They also fix and limit the range of interactive possibilities, affecting, for example, the degree by which the final user is – or is not – an active agent within the solar assemblage (Section 7.4.1).

Literature on standards highlights how these operate in complex and messy ways, representing a space of political action and contestation (Star and Lampland, 2009). Their normative dimensions are a "powerful, sometimes subtle, and sometimes not-so-subtle means of organising modern life" (Timmermans and Epstein, 2010: 70). Increasingly, life depends on a multiplicity of standards, making them into a pervasive but inconspicuous presence in the everyday. However, rather than mundane procedures, they should be seen as political projects (Barry, 2001: 26). In effect, resistance and the practice of politics often use standards as a mean of effecting power (Timmermans and Epstein, 2010: 70). Standards are a matter of permanent contestation, constantly exemplified by domains as diverse as the establishment of standards for food production or a change in parameters for staff evaluations in the workplace. Contestation also takes place through standards, as social movements or consumer groups, amongst others, demand the inscription of standards in law or adhere to pre-existing standards by insisting on compliance (Star and Lampland, 2009). Dean (2010) argues that through industrial standardisation, what is being normalised is not the material world of things, but the languages and communications required in an industrial society. From this perspective, standards are primarily about norms and the possibility of bridging the tension between law and freedom in a liberal society (Dean, 2010: 141). In other words, standards bridge sovereign and governmental forms of power.

6.2.3 Forging alignments and managing failures and contradictions

Forging alignments and managing failures and contradictions are proposed by Li (2007a) as crucial practices of assembling – a key dimension in the execution of the solar energy regime. Forging alignments is seen as linking the objectives of different agents involved in the governing efforts, both those who attempt to govern as well as those who are governed. Managing failures and contradictions is understood as an attempt to rectify deficiencies and correct breakdowns, as well as highlight the precariousness of the alignment forged. The constant need to forge alignments in the governing efforts points to "the will to govern as a point of convergence and fracture" (Li, 2007a: 268). Managing failures highlights "the ever-present possibility that an assemblage may disintegrate under the weight of its own contradictions or be reassembled in forms so different that they can no longer plausibly travel under the old name" (Li, 2007a: 287).

The confluence of practices of assemblage and governmental techniques illustrates the modes by which such techniques operate. In the case of solar technologies, this highlights the highly material nature of governing local energy, an provides insights on the factors leading to the success or failure of the new form of infrastructure. Scaling up SHW technologies as a form of urban infrastructure requires a particular type of material alignment between energy and water systems, in effect relocating energy dynamics within the domains of water (see also Section 5.4).

How governmental and non-governmental forms of power are mobilised towards transforming energy infrastructures in practice? How is the regime constituted beyond the discursive domains of the rationalities? These questions will be the subject of the remaining sections of this chapter.

6.3 Governmental techniques for the consolidation of SHW

Two contrasting types of governmental techniques are discussed in this section. In Thane, baselines, masterplans and targets operate as mechanisms to calculate energy and make local energy visible, construct the field of intervention and enable present action and future imagination. In São Paulo, the emphasis has been on the development of standards around solar energy knowledge and material qualities. These have been used to control quality and build reputation and, through this, qualify the human and material agencies at play. Whilst SHW standards exist in both countries,[14] the emphasis of this chapter is on São Paulo, where standards were a pervasive and extensive topic during interviews and instances of participatory observation. In contrast, in Thane the fieldwork research did not lead to instances where standards were discussed, suggesting a low emphasis on standards within the working of the city's solar energy regime.

6.3.1 Calculating energy in Thane: making visible, constructing the field of intervention and enabling future action

Drawing on ICLEI's '5 milestone approach' (Bulkeley and Betsill, 2003), Thane set out to develop an energy baseline, an energy masterplan and a set of

[14] SHW systems in India are required to comply with IS (Indian Standard) 12933 and IS 12976, centrally developed by the Bureau of Indian Standards (see Bureau of Indian Standards, 2013).

targets as the foundations of the emerging local governance of energy. Baselines render energy in the city visible, identifying amounts, locations and activities, and in doing so, establish the grounds for prioritisation and action. Masterplans construct the field of intervention by establishing descriptive forecasts and normative objectives, methodologies for becoming, exemplars, technologies and instruments. They also identify risks and suggest ways of avoiding them. Finally, targets bridge time towards the future, by allowing this future to be imagined and thus enabling action, so that energy becomes propositional. They also create points of connection between central and local government, providing rationalities for relationships across scales. Finally, they embody a specific episteme (a way of thinking about energy) as well as an ethos (a way of prioritising it).

The Solar City Baseline: the ways by which energy is made visible in Thane

For the first step in developing Thane's Solar City Masterplan, ICLEI supported the city in the development of a citywide energy baseline. As a form of statistics, city energy baselines fall within what is known as the 'science of the state': a form of "knowledge of the state in its different elements, dimensions, and the factors of its strength" (Foucault, 2009: 101). Statistics are a necessary feature for governing the conduct of the population, and thus developing a governmental regime (Foucault, 2009). With the local energy baseline, the statistical energy knowledge that traditionally rests at national levels (in the case of India via the annual Energy Statistics Report produced by the Central Statistics Office (Government of India, 2012)) gets into new hands. The development of energy knowledge at the scale of the city, commissioned by ICLEI – on behalf of the municipality – to a local consultant and achieved via surveys and direct data gathering at municipal offices, resulted in fine-grain data, leading to a greater level of detail. The holder of such knowledge lies in greater proximity with the object of knowledge (the sources of energy consumption). Energy knowledge has been re-territorialised, with the result of making energy visible at the local level.

Thane's energy baseline covered residential, municipal, industrial, commercial and institutional sectors. Data collection covered overall energy consumption in the city, including electricity, petroleum products, coal, biomass, and other energy sources. The baseline was produced for the year 2008, and was complemented with demand forecasting for the following five (to 2013) and ten (to 2018) years. The objective was to provide a firm basis for future action plans based on an in-depth understanding of consumption and use:

> *The idea was to include the survey to know how does the energy consumption act in the user. Because once you collect information from the different departments, in terms of how this energy is utilised by the end-user. That [consumption] we wanted to know, [so that] we can develop some type of action plan on those particular things (Interview P5).*

The quote above, by one of the professionals involved in the development of the baseline, illustrates how practices of energy use act as a key driver in this process of making local energy visible, with the ultimate goal of pursuing actions to influence such consumption. It also illustrates forms of knowing – the episteme of governmentality at play in a governmental technique. In Thane, when looking at all the energy sources combined (electricity, LPG, petrol, diesel, kerosene, CNG and SHW), the baseline concludes that "electricity is the major source of energy consumed by the city and needs attention for effective and optimal use through energy efficiency measures, DSM [demand side management] and application of renewable energy resources" (ICLEI, 2011: 23). Electricity makes up over 50% of the energy consumption of the city, whilst SHW accounts for only 0.18% (Figure 6.1). However, by explicitly including SHW in the calculation this form of energy is legitimised, in this way finding its place alongside more traditional forms such as electricity, petrol and diesel. The data collected were complemented with user surveys on the use of electric equipment and appliances, adding further layers of granularity and pointing to the specific uses of this electricity. The city's energy baseline, presented as a set of coloured charts and tables, revealed that the main electricity consumer is the industrial sector, reflecting the city's history as an industrial node. However, between 2003 and 2008, electricity consumption in the industrial sector grew less than 10%, compared to a growth of 60% in the residential sector and over 100% in the commercial sector (ICLEI, 2011). The growth trends in electricity consumption reflect the changing urban dynamics of the city: a rapid growth in the residential sector and associated commercial facilities, such as offices and shopping malls (Figure 6.2).

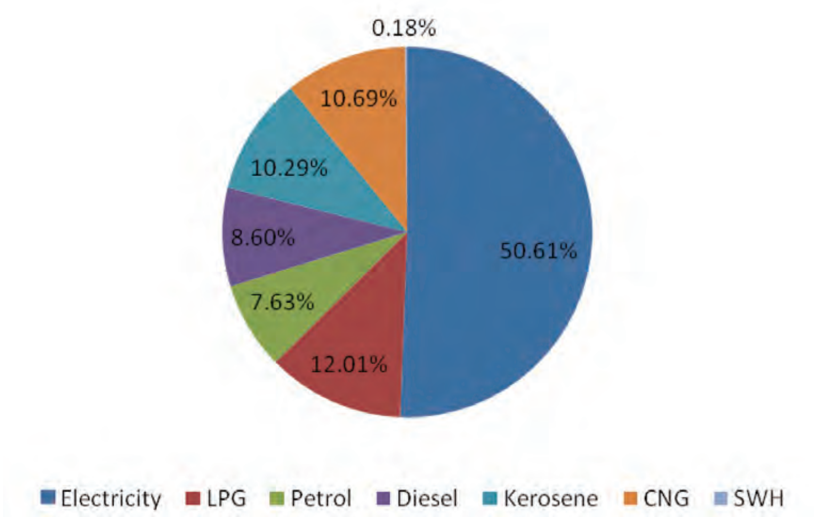


Figure 6.1: Thane's energy balance (ICLEI, 2011: 24).

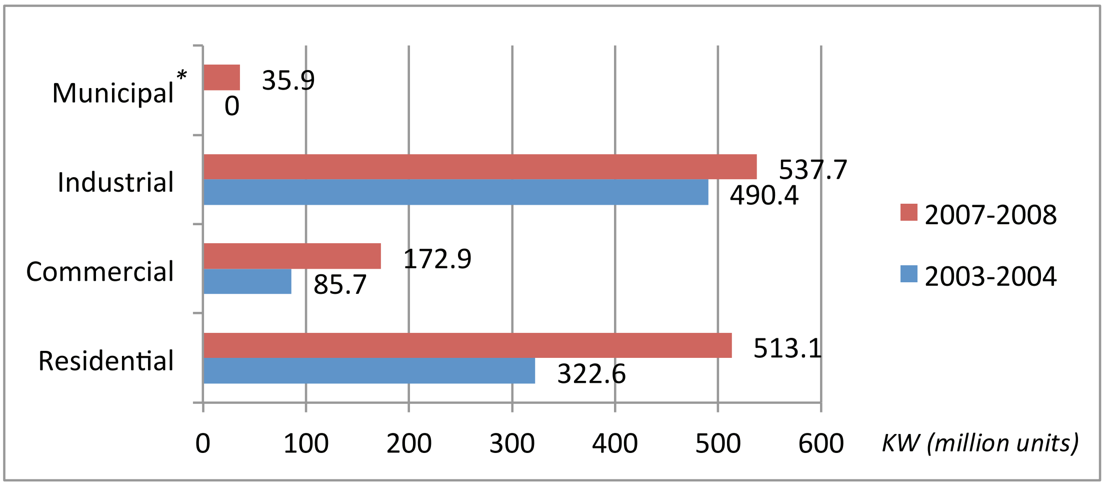
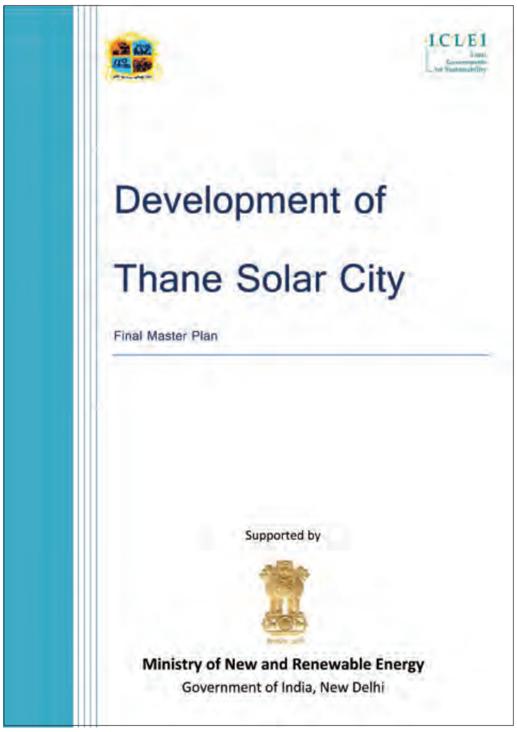


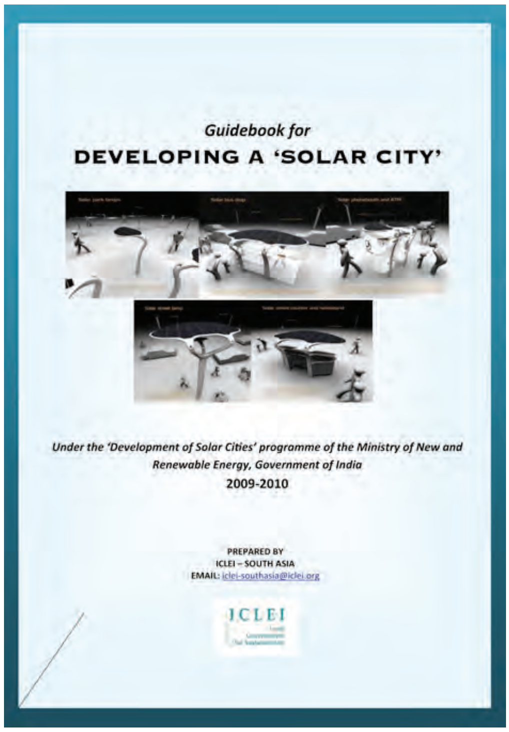
Figure 6.2: Thane's electricity consumption 2003-2004 and 2007-2008 (*no data available for 2004/2004; based on ICLEI, 2011).

For the first time at the city level, the urban energy baseline provided a full detailed breakdown of energy dynamics and, in so doing, created an object in need of governing. The energy baseline enabled a systematic understanding of the usage patterns and energy needs of the city and the services provided by the municipality, thus revealing the activities, locations and amounts of consumption. In doing this, it enabled the prioritisation of areas for intervention – an ethos. Its purpose of making energy visible is an explicitly stated objective (in this case, to achieve a greater understanding of the user and its consumption patterns). The baseline endorsed and extended the problematisation initiated by the governmental rationality around resource constraints (Chapter 5), providing a political rationale for action and developing a numeric language that politicians and the public can understand. Baselines embody a key governmental principle: the rational calculation as a prerequisite for action (Barnett et al., 2008: 629; Lockwood and Davidson, 2010: 394). They are seen as scientific and impartial guides, a perception that plays a role in supporting their legitimacy as a mode of intervention, often under the leadership of external agents (e.g. ICLEI). They provide local managers with statistics and numbers as well as access to a specialised and scientific language. Through this, it is possible for baselines to become the tools of action over other stakeholders that otherwise would resist the change. The baseline's visibility serves as a reference point for future comparison, and in this way, it is intimately linked to another governmental technique of the local governance of energy, the target. Both baselines and targets and are linked through a set of interventions consigned in Thane's Solar City Masterplan.

The Solar City Masterplan: constructing the field of intervention

In late 2011, both the Thane Municipal Corporation and the MNRE approved the Final Master Plan for the Development of Thane Solar City prepared by ICLEI. The masterplan is a comprehensive document composed of two volumes of nearly 150 pages each (Figures 6.3 and 6.4). The first volume is a generic document prepared by ICLEI for all the 11 cities where it led the development of city specific Masterplans (ICLEI, 2010). It outlines a generic methodology required to become a 'solar city', provides general information about renewable energy, and introduces the specific policy context in India. It also describes the origins of the solar cities concept, the ways in which other countries are using similar strategies, and the range of renewable energy technologies and energy efficiency measures available. This first volume finishes with generic information on financial models, mechanisms for increasing public participation in energy initiatives, and strategies to identify and mitigate risk associated with the efforts of implementing renewable energy and energy efficiency in cities. The second volume is specific to Thane, and presents the current energy scenario of the city with demand forecasts (the energy baseline). It also proposes a set of energy efficiency and renewable energy strategies, along with an action plan, budget and implementation strategy composed of awareness-raising activities (see Section 7.3.2), the implementation of pilot projects, and an account of the resulting possible 'carbon market benefits' (ICLEI, 2011).





Figures 6.3 and 6.4: Thane Solar City Masterplan – main document and accompanying Guidebook for Developing a 'Solar City' (ICLEI 2011; 2010b).

The Masterplan is the key document that frames and establishes in Thane the field of intervention of the Solar City Programme. This is done through a variety of means: it defines how the future looks, both in descriptive and prescriptive ways (forecasts and objectives); it establishes ways of becoming (methodologies) and signposts possible paths (exemplars); it defines the range of available and valid energy interventions (technologies); and finally, it establishes the mechanisms for achieving the objectives (instruments). The Masterplan also identifies the agencies likely to derail this journey (risks), and proposes ways for dealing with them. The Masterplan predicts an almost threefold population increase by 2041 and a corresponding 40% increase in electricity consumption by 2018. It translates what a target of 10% reduction in consumption would mean in energy figures, settling for 230 mKW of electricity for 2013. It defines from which sectors and how this reduction is to be achieved: solar water heaters, solar cookers, solar lanterns, solar PVs, biogas installations, waste-to-energy facilities and renewable energy interventions in homes, hotels, restaurants, hospitals and factories, amongst others. These interventions draw inspiration from national and international experiences, such as Freiburg 'Solar City' and the Solar Cities America programme, and are to be delivered via campaign publicities, technical assistance, subsidies and financial incentives, ESCOs, audits, training programmes and a multiplicity of other mechanisms. The agencies of technology (e.g. poor design, quality and installation), the economy (e.g. high upfront costs), labour (e.g. unavailability) and policy & regulation (e.g. delays in incentives) are highlighted as risks to be mitigated.

To achieve its goal – "the success of renewable energy technology" – the Masterplan relied highly on calculation techniques, developing "an accurate resource assessment and its potential in the city" (ICLEI, 2011: 5). This looks in detail at local conditions, such as the city's solar, wind and biomass availability and waste generation, and selects the "most techno economically viable renewable energy options" (ICLEI, 2011: 38). Technical feasibility, commercial availability and the generation of “attractive” financial benefits from energy savings were the key criteria.

The Masterplan operates through the antiseptic scope of the technical rather than the political, becoming a tool for change within the status quo. Drawing on Li’s notion of anti-politics (2007a), the Masterplan can be seen as a governmental technique that, by concentrating on the technical, avoids relevant political questions around the energy-city interface. It does not consider what this energy is for or for whom; who benefits and who does not through the change towards renewables; or how the planned (formal) and unplanned (informal) areas of the city might get differentiated access to such new energy forms. Through an alignment with the City Development Plan (Thane Municipal Corporation, 2006), urban growth and its energy needs are naturalised. Thus, the Masterplan provides strategies that help cope with the energy demands of urban growth, without discussing the distribution, forms and intensities of growth itself or its implications in energy terms.

The reterritorialisation of energy via governmental techniques in the form of a Masterplan led to specific material/technological outcomes. The Solar Cities Masterplan highlights the significant role that solar hot water, as a replacement for electricity, plays as a form of energy that can be produced locally. In the residential sector, as “electricity is the major fraction (49%) of energy consumed”, SHW systems play the leading role in reducing energy consumption (ICLEI, 2011: 41). Targeting a transition of 10% of households using electric water heaters to SHW over the course of five years, the Masterplan provides detailed calculations for annual electricity savings achieved via SHW of 40MU and emissions reduction of 32,466 tCO_2. This is equivalent to 8% of the total residential electricity consumption of 2007/08.

Thane’s Solar City Masterplan empowers SHW as the main technological intervention in this process of becoming a ‘solar city’. This conclusion is achieved in recognition of cost limitations leading to the identification of non-state funding mechanisms. The growing residential nature of Thane and the possibility to fund a significant part of the required renewable energy via resident's investment in SHW plays a key role in the prioritisation of this technology:

> *Considering the high upfront / capital costs of solar equipments in India SWH has proved to be the least cost option compared to other solar equipments for TMC [Thane Municipal Corporation]. As TMC is primarily an urban residential area, the potential for investment lies more in/from individual households.*
>
> *Thane Solar City Masterplan (ICLEI, 2011: 6).*

This quote conveys the existing tension between the will to improve and the limitations of the local level to deliver it. It also illustrates how the citizen, in the form of individual households, becomes the Masterplan's key instrument (see Chapter 7 for further discussion). As a technique of government, the Masterplan enables local control through calculation. However, this control is limited in the face of tight local financial conditions. Thus, governmental techniques become crucial also as a way to encourage and assemble investment in order to realise delivery. In Thane, funding constraints force the local level to look for private funding sources (the household) for the primary strategy associated with the achievement of the local energy strategy (SHW). In an example of scalar energy politics, developing the local governance of energy depends on multiple agents beyond the local state, from the agencies of the final user to those of the central level and its drive to align its objectives with those of the municipality via targets.

Renewable energy targets: enabling possibilities for acting in the future

Targets provide the main normative element of Thane's Solar City. As a technology of government, targets (alongside monitoring devices, appraisal and feedback mechanisms) "dominate and structure the actions of local players"

(Raco and Imrie, 2000: 2198). Like other governmental technologies, they actively define “the domains which are to be governed” (Murdoch, 2000: 513). They operate as a communicative device, transforming the proposed intervention into discrete, visible and easy-to-comprehend snippets of information. Targets also have an important temporal dimension, representing ideal futures and aspirations, linking present and future in quantifiable ways, and benchmarking the future, thus playing a fundamental role in imagining it. Through targets, the future performs a governance role in the present. It is the final calculative event, where the knowledge gathered through the baseline and the mechanisms defined through the Masterplan are played out towards unlocking and controlling the future.

In the case of the Solar Cities Programme, all participating cities commit to a target of 10% per cent reduction in the projected demand of conventional energy over the course of five years. Half of this reduction is to be achieved via renewable technologies and the other half via energy efficiency. As a generic target applicable to all cities, it responds to the central energy planning in the hands of the MNRE and the need to reduce energy consumption on a national scale (Section 5.3). The targets of the Solar City Masterplan represent a moment where central energy planning and the emerging local energy governance meet and establish dialogue. In Thane’s Solar City, despite the absence of monitoring mechanisms, the presence of generic targets reflects a central command and control strategy rather than a specific feature of the emerging local energy governance. They can also be read as the national elements that are part of the local governance of energy. In line with other studies on the use of sustainability targets and indicators as governmental technologies, targets here appear to function as a mechanism emerging from the central government “play[ing] a role in the mediation of central-local relations… [and] enrolled in the monitoring of local government” (Rydin, 2007: 621).

In Thane, there is an expectation that the emerging governance of climate change in India at national and state levels (Sections 2.4 and 5.3) will play a significant role in the future in providing funding for energy initiatives that will contribute to the achievement of the targets. This is illustrated by the ICLEI staff member who prepared the detailed breakdown on how to achieve the Solar City targets, who states: "I don't see that local government alone can achieve this complete target". Given the funding limitations of the local level, and in an example of the scalar interplay between the local energy regime and climate change rationalities, he expressed his expectations that the funds allocated for the National and State Action Plans on Climate Change will link to the energy initiatives of the Solar Cities Programme. In his view, "state governments and central governments have to help with this…Because [Thane's Solar Cities Masterplan] will help us to achieve the national [GHG] target" (Interview P5):

> *…most of the cities do not have the funding for the renewables; what they have is like peanuts. So state governments and central governments have to help this… now the government has these schemes that are coming out like the State Action Plan on Climate Change, which is being developed in line with the National Action Plan on Climate Change. So obviously, this state government may create some funds to implement this project (Interview P5).*

This quote illustrates how, in the case of Thane, Solar City targets operate as a relational device between different government levels. They reflect a desire for control from the central level to the local, yet they are also mobilised as a justification for support thanks to an alignment of objectives across different levels. In their mediation between present and future, targets become linked to climate change rationalities and to the financial support of central and state governments.

The limitations of calculative techniques

Whilst the three calculative techniques discussed succeed in making local energy visible, and in making residents visible as a funding source, they fail to make the citizen in his/her political condition apparent. Beyond the broad categories of 'residential', 'commercial', 'municipal' and 'industrial', the techniques of calculation failed to ask questions about the nature of those consuming this energy, particularly in relation to their social conditions. Thus, they consolidated the energy problem as a technical rather than a political matter (Section 7.5). Making local energy visible through baselines, targets and masterplans also failed to point to the multiple material relations involved in the local making of this energy and to bring to the forefront the material relations that underpin these new energy forms. In focusing attention on making energy visible through numbers and percentages, these techniques occluded other important resources and forms of urban infrastructure involved in the solar energy regime, such as water and its infrastructures – particularly important in the case of SHW. In contrast to Thane, the agencies underpinning the local governing of energy in São Paulo do not depend so much on calculation and ways of making visible, but in the standardisation of knowledge and materials. This leads to a different type of engagement with the material worlds of local energy, one that is more focused on the domains of provision and use and on the technical systems required.

6.3.2 Standardising solar energy: governing knowledge and materials

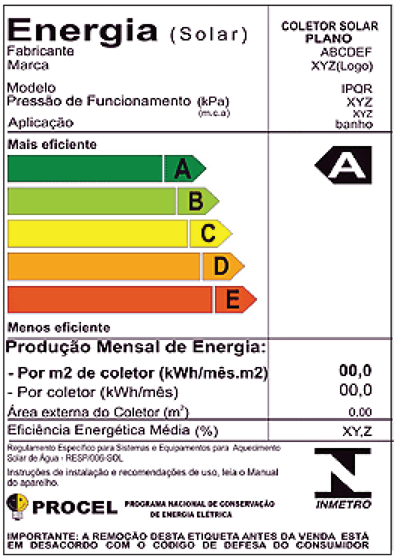
Standardisation is defined as "a process of constructing uniformities across time and space, through the generation of agreed-upon rules" (Timmermans and Epstein, 2010: 71). Standards specify material properties and performance, operating in a relational nature by enabling a multiplicity of subjects and objects to work together across distances. They are also a social product, often emerging from and legitimised by an external knowledge body, such as a professional association, an industrial agency or the state (Timmermans and Epstein, 2010). Like modes of calculation, standards define what is good, acceptable and bad, operating as a normalising technique (Busch, 2000). In the solar energy regime, standards operate through a codification of material relations and knowledge

(Law, 1999; Section 3.5), defining the field of action, marking access points, enabling or blocking points of passage, and limiting the range of interactive possibilities. Standards control the agencies involved, regardless of their human or non-human quality.

Industry partners in Brazil play a strategic (and often leading) role in the development of national standards and certification mechanisms aimed at regulating quality and promoting innovation (Lopes de Souza and Hasenclever, 2011; Oliveira et al., 2010). The Brazilian solar industry relies on processes of standardisation to establish quality and reputation. In this way, it opens or closes possibilities for market development and, in effect, regulates the market. This codification process sees state and industry working together under governmental logics, with industry taking voluntary and leadership roles in establishing mechanisms for self-control. In São Paulo, SHW systems are tightly governed by a complex web of voluntary standards, certifications and quality development initiatives – some of them operating on a national scale whilst others are restricted to the city.

Standardising material relations

The two main standards regulating the SHW industry in Brazil are the Brazilian Labelling Programme, the national energy labelling system, and the National Programme for Electricity Conservation (PROCEL) Seal, an electricity conservation certification coordinated by Eletrobras and the Brazilian Ministry of Mines and Energy. The Brazilian Labelling Programme focuses on energy efficiency and performance, labelling SHW equipment using a colour-coded classification system similar those used in other countries (Figures 6.5 and 6.6). All equipment rated 'A', the maximum rating, automatically obtains the PROCEL Seal. Manufacturers interested in getting their equipment certified send samples of their equipment to the Brazilian National Institute of Metrology, Standardization and Industrial Quality (INMETRO), the entity in charge of performing tests and awarding certificates. The Brazilian Labelling Programme evaluates the material performance of SHW systems by testing both solar collectors and hot water tanks, focusing on material strength, durability and performance (under strenuous climatic conditions and a variety of water pressures), and thermal stress (examining how the materials respond to abrupt changes in temperature). Energy performance is also evaluated through an analysis of the energy generated per collector area (kWh/month/m^2) under simulated and controlled solar radiation conditions, alongside analyses of thermal efficiency and performance (INMETRO, 2012a). At the time of fieldwork in São Paulo, the standards were voluntary, and the possibility of making them mandatory was being discussed between industry representatives and INMETRO. According to data provided by INMETRO, as of 2011, 216 models of SHW for domestic use manufactured by 40 different companies had acquired the certification (Borges, 2011). In 2012, INMETRO issued regulations making the Brazilian Labelling Programme for SHW systems mandatory for all products commercialised from 2015 onwards (INMETRO, 2012b).



Figures 6.5 and 6.6: Energy label for SHW systems developed by INMETRO (INMETRO, 2013) and SHW system based on flat plate collector technology in social housing in Cubatao, Greater São Paulo Brazil. Note the PROCEL Seal on the tank (red, yellow and black) and INMETRO's sticker (top left corner of the collector), as part of the Brazilian Labelling Programme.

The application of standards to material properties is intended to ensure that the energy delivery of SHW systems (performance) matches agreed-upon expectations (quality), regardless of the individual material agencies involved. The primary emphasis is on infrastructure stabilization rather than resource 'visibilisation'. Nevertheless, through the analysis of energy performance, energy is made visible and alignments are forged with governmental rationalities around resource security (Chapter 5). Evaluating performance means making material relations into a form of knowledge and through this deploying the episteme of the regime. Securing performance and quality rely on both human and material agencies, as illustrated by forms of standardisation that have knowledge around SHW as their primary target.

Standardising knowledge

The forms of standardising knowledge examined illustrate how agents within the construction sector seek to both self-regulate and regulate others. Two of the cases examined are explicit in their intent to regulate by incorporating the principles of São Paulo's Solar Law within professional practice, whilst the other informed the drafting of the Law. They also illustrate how the solar sector reaches out to other sectors, shaping their conduct in the process of mainstreaming solar energy. With this broad reach, standards here specifically target supply companies, design professionals and their construction practice, and solar professionals in their solar technology installation practices. The three examples of the standardisation of knowledge around solar energy examined here are the Brazilian Supplier Qualification Programme for Solar Heating Systems (QUALISOL); the *Specification Guide for São Paulo's Solar Law* (ABRAVA, 2008); and the training programme on SHW developed by DASOL.

The first example, QUALISOL, was established in 2005 by INMETRO and PROCEL in partnership with DASOL. It is a voluntary certification system targeting supply companies rather than products. It includes companies involved in the manufacture, retail, design, installation and maintenance of SHW systems. At the time of writing, according to its web page, the programme was in its ‘pre-qualification’ stage (Eletrobras, Undated). This meant that the certification was acquired by post following a written commitment on the part of suppliers to adhere to best practice standards developed by DASOL, including a commitment to only use INMETRO rated equipment (PROCEL/ABRAVA, 2007). A second stage is planned, where maintenance of the certification is contingent on qualification exams to be taken by the staff members of companies involved.

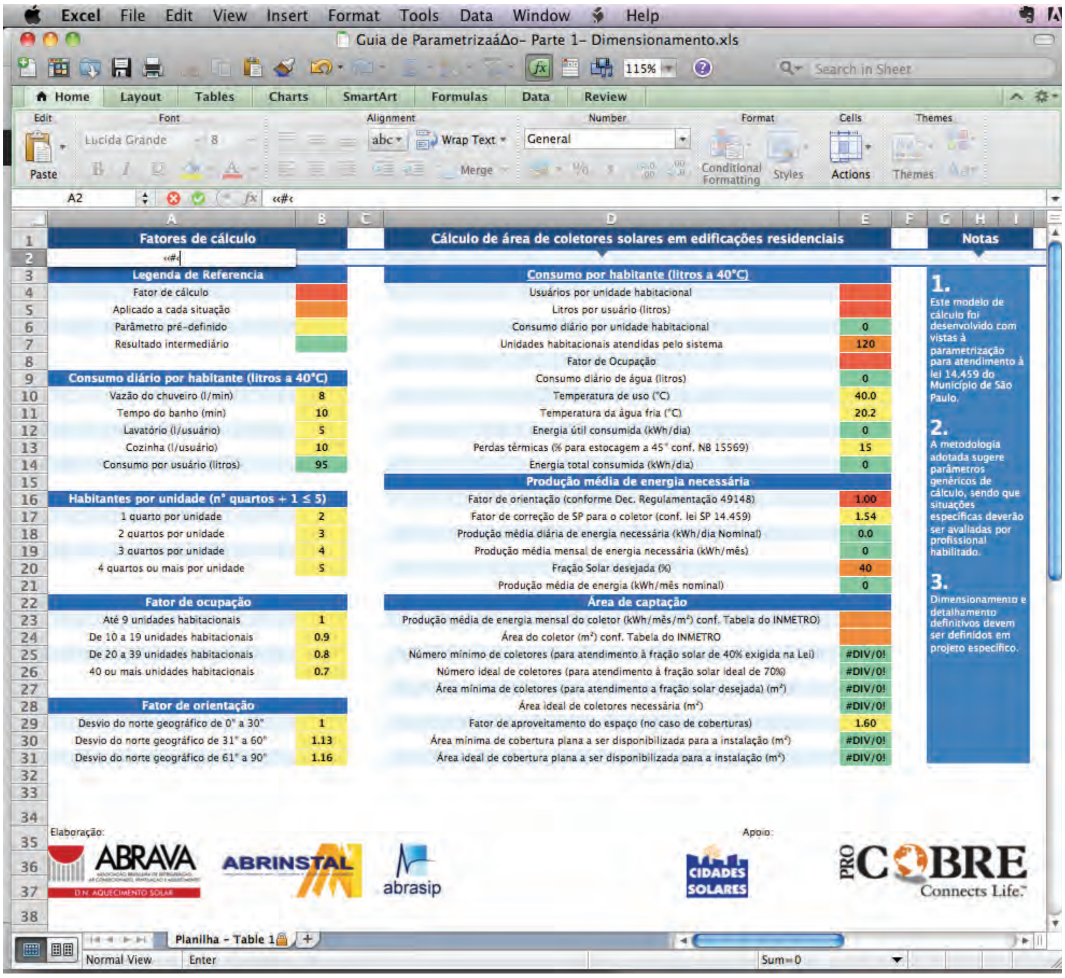


Figure 6.7: Screenshot of the *Specification Guide for São Paulo’s Solar Law* (ABRAVA, 2008)

The second system is a form of design standard specific to the implementation of the Solar Law in São Paulo, targeting engineers and architects involved in the design of residential towers. It illustrates how standards operate in a relational way to direct the energy conducts of the different agents involved in the building sector. The *Specification Guide for São Paulo's Solar Law* (ABRAVA, 2008) consists of a written methodology and a Microsoft Excel template to calculate in a simple way the number of collectors and minimum building roof size required for a SHW system capable of providing at least 40% of the building's water heating needs via solar energy. The 40% standard responds directly to the city's Solar Law, and is in direct recognition of governmental rationalities around resource constraints (Figure 6.7). The template is available for free download on the Internet. It was developed jointly by three industry associations: DASOL, ABRASIP (the Brazilian Association of Engineering Building Systems; an association of designers) and ABRINSTAL (the Brazilian Association for the Compliance and Efficiency of Facilities, an association of system installers).

The final example of standardising knowledge around SHW is the training provision that DASOL makes available to members of the solar and construction industries as a key element for maintaining quality within the country's growing SHW market. This form of standardisation targets professionals. When São Paulo's Solar Law was launched (Section 6.5.1), DASOL coordinated with other professional associations within the construction sector in order to provide training on the installation of SHW systems. They also played an important role in training professionals at the CDHU on the functioning of SHW systems, an important step in the CDHU's process of adopting the technology. In addition, DASOL runs an extensive annual schedule of courses covering a broad range of subjects, from installation procedures to legislation and policy context. Through courses, they play a significant role in promoting specific (codified) ways of dealing with SHW systems.

Controlling the market: INMETRO and the Brazilian association of SHW manufacturers

All standards mentioned have been developed with substantial participation from the SHW industry, represented by DASOL. In this way, membership in DASOL gives manufacturers the power to determine what constitutes solar energy and what does not. This power embodies a telos, given its attempt to develop ideal energy forms. It also embodies an ethos, in its embrace of modes of operation characteristic of the private sector and through this a requirement for formal structures of action. It also means engaging in a form of self-government through voluntary compliance to agreed codes of conduct. In a professional magazine edited by DASOL and widely distributed amongst the SHW community, the coordinator of INMETRO's Labelling Programme highlights the importance of working together with industry for this purpose:

> *Unlike other countries, here in Brazil industry players are active partners for the success of quality assessment programmes. INMETRO… maintains an open dialogue with all sectors of society involved… The result is the implementation of a labelling programme in continuous improvement and final products that are increasingly more affordable and competitive (Revista Sol Brasil, 2010: 14, translated from the Portuguese).*

Standards are actively promoted amongst industry members as well as members of the public. For example, through booklets and graphic brochures, DASOL and INMETRO generate public awareness, informing the public of the benefits of the energy label and suggesting the exclusive use of suppliers holding QUALISOL certifications when buying SHW systems. Such brochures refer to QUALISOL as a mechanism to indicate "to the general public that those suppliers have the required *degree of confidence* in accordance to the requirements… *all of this to guarantee your satisfaction and the sustainable growth of such market*" (INMETRO, 2008: 4; original emphasis). In promoting the standards, these brochures also generate awareness of SHW systems by providing detailed explanations of why and how it functions, whilst enrolling citizen identities in the governing of both energy and water (examined in more detail in Chapter 7). They justify the adoption of SHW on economic grounds via a reduction in energy bills, alongside a reduction in peak electricity loads (which in turn save the country from investing in additional generation facilities), greater energy security in the face of unpredictable weather impacting hydroelectric plants, and the conservation of the environment. Furthermore, when drawing attention to the possibility of SHW systems using more water when compared with electric showers (see Section 7.4.2), the brochure points directly to issues of citizen responsibility in reducing consumption. This is exemplified by the following quote explaining the benefits of SHW, taken directly from the brochures (Figure 6.8):

> *…so that you reduce your electricity bill; so that Brazil* ***reduces*** *the electricity load of the peak hour and* ***avoids*** *investing millions in constructing hydroelectric or nuclear plants; for society, as there is* ***less*** *dependency on Saint Peter [the Catholic saint who, within Latin American popular culture, controls weather patterns] for the generation of electricity; and for the preservation of the environment.*
>
> *…The SHW system can function with …3 litres per minute! But in the market, there are showers with greater consumption. That choice is a matter of common sense and individual responsibility! More than that, it is a matter of* ***citizenship****!*
>
> *(INMETRO, 2008: 10 & 12; translated from the Portuguese, original emphasis)*

Thus, standards developed by INMETRO play a double role by maintaining quality in the market, ensuring that the sensitive reputation of an emerging technology is not affected by low quality systems entering an expanding market, whilst also promoting, explaining and justifying SHW use. Their power becomes amplified as stakeholders adhere to them and incorporate them in their procurement models. For example, the CDHU requires SHW systems with an 'A' rating for social housing, and QUALISOL certification from all manufacturers and suppliers involved (Sections 5.4.2 and 7.5). In a similar way, São Paulo's Solar Law requires all systems to be installed in the city to have been rated under the Brazilian Labelling Programme. According to the staff member of the municipality

Figure 6.8: INMETRO's brochure for the promotion of quality standards for SHW - cover, and pages 3, 9 and 12 (INMETRO, 2008).

in charge of drafting the Solar Law, this decision was taken in order to ensure the public's long-term adherence to SHW systems (over other forms of water heating) by securing user satisfaction:

> *…another thing that we need to be careful about, in order not to compromise the quality of the technology, was to request INMETRO rating. That was to avoid people putting in place equipment that was not going to last. If the equipment starts losing its efficiency, users would start complaining that the solar hot water system is not good and does not work. Then they would get rid of the system and replace it with gas… or with electric showers (Interview P21).*

Yet not everybody within São Paulo's solar energy regime agrees with the way quality standards are being developed and used. Quality standards are constantly challenged and contested within the industry. On one hand, several energy consultants and dealers interviewed criticised the standards for being too lenient and in this way stifling innovation. For example, the owner of an energy services company argued that "once a company achieves the 'A' qualification of INMETRO, there is no more incentive to improve the technology. But this 'A' level has been achieved with a technology that is poor and basic" (Interview D21). On the other hand, standards have become material 'obligatory passage points' determining who sells solar energy to whom within this new energy market. Those agents within the assemblage that attempt to bypass Brazilian manufacturers by distributing solar collectors imported from China claim that INMETRO's standards give national products an unfair advantage and block imports from accessing important markets such as social housing. In contrast to the traditional copper-based flat plate collector (Figure 6.6), Chinese SHW imports are based on evacuated glass tubes, a different type of technology for SHW that is not manufactured in Brazil (Figure 6.9). At the time of fieldwork, despite the higher energy efficiency of the evacuated tube systems, dealers interviewed claimed that evacuated glass tubes were receiving lower rankings in INMETRO's certification system. Standards and certifications also exclude alternative technological configurations of SHW from the market. This is the case of the DIY SHW systems promoted by the non-profit *Sociedade do Sol* (Section 7.4.1; Figure 6.10): given their DIY nature and their reliance on cheap materials, these systems lack the high specifications of commercial systems and therefore cannot achieve the standards developed by INMETRO, blocking their entrance to important markets such as the one provided by the CDHU in social housing.

Figure 6.9: SHW system based on evacuated tube technology in Thane.

Figure 6.10: DIY SHW system installed at the roof of offices of the *Sociedade do Sol*, in São Paulo.

Through the embodiment of material relations and knowledge into standards, a new know-how renders docile "the unruly domains over which government is to be exercised, to make government possible and to make government better" (Miller and Rose, 2008: 204). Standards operate as governmental techniques, but also create forms of knowledge, bringing on board the epistemic dimensions of governmentality. As a form of anti-politics and a way of authorising knowledge, they render technical questions around who is entitled to join the solar energy market and define legitimate knowledge sources and forms. In contrast to the experience of Thane, standards in São Paulo play a key role in the solar energy regime. They define the field of action and enable or block entry into the emerging local modes for circulating solar energy and profiting from it. A particular type of material circulation is at stake: the circulation of energy across water.

6.4 Forging energy alignments: a local way of making energy out of water

An important characteristic of the way in which the local governance of energy is playing out in Brazil and India is through an integration of energy and water infrastructures. This was initially examined in Chapter 5, where, through the case study of São Paulo's CDHU, the thesis discussed how the solar energy regime operates by drawing on rationalities capable of incorporating the energy embedded in local water dynamics. This section builds on such argument, by examining in detail the type of material alignments involved, and reviewing the seemingly trivial yet fundamental socio-material configurations that enable the circulation of energy through water. Scaling up SHW systems in the city requires a specific type alignment between energy and water infrastructures. Such alignment traverses knowledge and material dimensions. In forging this alignment, the techniques of government come into play, are tested and/or resisted. Within the context of global and national energy strategies, SHW is about replacing electricity. Yet, in the implementation of this energy mode, SHW is about water and its circulation through an arrangement of material agents, and thus, it is about pipes, return valves, insulation, water meters, faucets and tanks. As a SHW dealer in Thane explains, "it is a plumbing job!"

6.4.1 Hydraulic assemblages and plumbing knowledges

Making energy in the city – through SHW systems – involves a multiplicity of human and material agents and relations working in tandem: a solar assemblage. As all assemblages, the solar assemblage is extensive, with hard to define boundaries and multiple edges, innumerable agents and an infinite set of relations at play. Yet, whilst there are myriad actors involved, those who materially assemble energy locally are the manufacturers, dealers and installers (Figures 6.11 and 6.12). They traverse the city building relationships with clients, explaining SHW, delivering system parts, devising specific material arrangements of collectors, tanks and pipes, and piecing together the arrangements they designed. Their knowledge is the key literacy involved in making this local form of energy.

Figure 6.11: Dealer of SHW systems performing a site visit, Thane.

Figure 6.12: Installers of SHW systems, Thane.

The energy generated by SHW systems relies on water storage and circulation dynamics, and thus plumbing is an essential part of solar water heating. Hydraulics, the technical knowledge of the movement of liquids through channels or pipes, is both a key literacy and a calculation required for this water based solar city. However, this is not the 'big' hydraulics of Brazil's hydroelectricity. Rather, it is the smaller and more discreet knowledge of the plumber, of water flows through domestic pipes. Knowledge and involvement in SHW systems often evolve from knowledge of hydraulics, such as in the case of Jain Irrigation Systems, one of the three biggest manufacturers and distributors of SHW systems in the State of Maharashtra. The company has over 50 years of experience dealing with water and pipes: first with sprinkler systems for agriculture, macro-irrigation and water pumping, and, more recently, SHW systems. The staff member in charge of distributing SHW systems in Thane, who originally trained in plumbing and sanitation, sees hydraulics and plumbing as the right type of knowledge for the job. As a sales representative working for another SHW manufacturing company explains,

> *…unless and until you do a good plumbing work, it is very difficult. [If] there is a problem of leakage of water, then [there is a] problem of wasting of energy. Proper plumbing should be there… proper insulation all comes under plumbing only... otherwise [the sun] will heat the water [and] by night, it will get cool... (Interview D15).*

Yet, in the Thane solar assemblage, knowledge around the energy-water interface is not easily available and circulates only in informal ways. Whilst in São Paulo DASOL plays a key role in providing formal training on SHW systems, a form of standardisation of knowledge that also operates as a governmental technique, in Thane dealers and installers interviewed complain about a lack of formal knowledge sources. In the words of a local dealer, “there is no such thing initiated by the government or the manufacturers or anyone, where you can go and learn it. There are no courses. Nothing is there for solar” (Interview D2). Knowledge is acquired by going to industry exhibitions, spending time with colleagues who have greater knowledge about SHW, and interacting with manufacturers. Most often, it is a process of learning by doing. In addition, often, as one dealer of SHW systems puts it, “the major source is the internet” (Interview D10). Despite efforts by the UNDP-GEF’s Global Solar Water Heating project to increase SHW knowledge amongst those involved in the solar industry in India (UNDP, 2010), in Thane’s solar assemblage knowledge is acquired on an ad hoc basis.

6.4.2 Governing material qualities

Energy through SHW systems is produced through the material flows that result from an extensive arrangement of material alignments. It requires water to move continuously from collector to tank in order to absorb heat, pushed by the density differentials created by heat itself in the water molecules. Water then moves, through the dwelling’s pipes, towards the bathroom, transferring the sun’s energy from building roof to the user. In this journey, cold water is displaced and discarded, as hot water makes its triumphant arrival into the practice of showering. At different points, the pressures of cold and hot water compete against each other. In some instances, one overcomes the other to enable circulation; in others, both need to be equal if the system is to work. Success is not only about the delivery of hot water, but also about the achievement of the right mix between cold and hot. This is obtained through the right inclinations, pipe sizes, valves, materials, and if need be, pumping strategies. Pipes need to have the right insulation; they need to be reduced at each floor; taps need to have the right valves; tanks need to have the right thickness; glass needs to have the right density; collectors need to have the right materials. This is an indication of the material relations involved in a fragile solar assemblage (Figures 6.13 to 6.15).

Figures 6.13, 6.14 and 6.15: Material relations: water outlet from hot water storage tank to collector (top left), and hot water piping linking the SHW systems with each flat (bottom left and right).

SHW manufacturers point to how the quality and performance of SHW systems is defined by the nature of its multiple material components. Advancement in the SHW industry is driven more by material quality rather than the development of complex technological knowledge. Given the type of exposure of SHW systems to the natural elements, the quality of the materials involved is vital for performance and long-term durability. As explained by the technical director of a large SHW manufacturing firm located in Bangalore, SHW systems are exposed to harsh environments from the outside, where they receive the sun, wind and rain, and from the inside, where they receive low water quality. He points to how, whilst cheap SHW systems can be manufactured in small and almost domestic industrial facilities, large manufacturers have taken significant steps in improving product quality via research and development in material technologies (Interview D14). Another representative of a manufacturing firm in Bangalore points to how “you can use recycled, second hand metal and still get away with putting out [manufacturing] a water heating system” (Interview D12). Here lies, in essence, the main difference between the more affordable (and lower quality systems) and the more expensive high quality products. In his view, to ensure quality, the SHW manufacturing industry needs to use “the best quality materials, the best quality design… we use very high quality, tested and certified copper, or steel, or aluminium, or glass, which is a very essential to make your product really good” (Interview D12).

Governing the material configuration of SHW systems in extensive detail – something that is achieved via, for example, standards – has an impact on the overall success or failure of the effort to scale up SHW. This involves controlling the qualities associated with the material of the fins that collect the sun’s heat (copper vs. aluminium), the coating paint covering the fins in order to enhance heat absorption, the type, density and amount of insulation used to maintain the heat in the collector, the type of glass allowing solar radiation to enter into the collector (plain vs. toughened), and the base material and enamelling used for the hot water storage tank, amongst others (Figures 6.16 to 6.18). Whilst São Paulo’s emphasis on standardisation techniques has been successful in controlling these material alignments, Thane’s emphasis on calculation techniques fails to make them visible, signalling the emergence of resistances and breakdowns in the emerging solar energy regime. Knowledge scarcity around SHW systems and a limited attention to processes of standardisation impose limitats on the success of the material alignments required for making energy in the city.

Figures 6.16, 6.17 and 6.18: Manufacturing plant of SHW systems in Bangalore: collectors assembly line (top), testing unit for hot water tanks (middle) and glass panels ready for assembly.

Ungoverned materials: quality and performance challenges in Thane

Unlike in São Paulo, the fieldwork research in India did not lead to discussions around processes of standardisation of SHW. Manufacturers interviewed in both Thane and Bangalore, where the majority SHW systems are manufactured in India, repeatedly spoke about how Thane's Solar Law is having a negative impact in the solar industry. In their view, this is the result of the recent high local demand for SHW systems, which encourages small entrepreneurs to establish "small-scale and unregulated" business manufacturing products of low quality (Interview D12).

Interviewed manufacturers of SHW systems in India claim that many customers in Thane are buying low quality and substandard equipment prone to breaking down after only a few years of operation. This is the result of the use of low-quality materials and a limited knowledge base among those involved in system design and installation. In the view of the marketing director of a manufacturing firm in Bangalore, given the increase in small SHW manufacturing business, the Solar Law affects "sales, but more than that, it affects solar technologies, and the confidence, and the reputation of the technology" (Interview D12). Quality within the industry, and the impact that low quality has on the reputation of SHW systems, is seen as the main challenge for implementing SHW in urban areas. In Thane, when talking about the impact of the Solar Law, one sales representative working for a manufacturing firm refers to the challenges associated with the low quality of the systems that are being distributed in the city:

> *…the technology will get the bad name because of that. That is the major thing happening in Thane... People are not aware of the quality, whether it is working properly or not… That is the biggest challenge we are facing… Everybody is running behind reducing the cost. Now that will again reduce the efficiency; that will again reduce the quality of the product; that will also reduce the life of the product. And ultimately, that will give a bad name to the technology. After sometime the people will say, "the system doesn't work; the system is a failure" (Interview D5).*

The quote above shows how, in the context of mandatory provisions requiring the installation of SHW systems, the drive for low cost coupled with a practical absence of standards affects quality. This lack of quality and performance is not only the result of how SHW systems are manufactured, but also of how they are installed. This is evidenced by the challenges associated with making energy, water and housing infrastructures work together for the purpose of generating energy locally.

6.4.3 Overcoming the incompatibility between water and energy systems

Whilst largely successful, São Paulo's experimentation with SHW in social housing (Figure 6.19) has also been fragile and prone to breakdown. SHW manufacturers point to the inherent difficulties of incorporating SHW in pre-existing social housing typologies that did not consider it from the outset. For the CDHU, putting in place solar infrastructures meant investing time and effort in solving a multiplicity of small problems emerging out of this integration of systems (achieved over time through an evolving system of contracts and terms of reference for the provision of SHW). It also meant establishing the limits of solar energy within social housing: the limited alignment in the water-energy interface means that SHW can only be installed in residential towers with five stories or less. Governing SHW means both forging alignments between different utilities and their respective infrastructure networks, but also recognising failure and developing ways to overcome it.

The challenges of getting water meters and SHW systems to work together

With the exception of social housing, water metering has never been a common practice in São Paulo's residential sector. Yet it is one of the main requests of social housing residents. In the past, the absence of individual water metering often resulted in social conflict, given the variable payment ability of each family.

In residential towers, in the absence of individual meters, the water bill would be equally divided amongst all families. However, when a family could not provide its share of the bill, the entire building would risk getting their water service stopped by the water utility company. The introduction of individual water meters was a step forward in solving this problem. This technique is being used by the CDHU as a strategy for lowering social conflict in their dwellings (Figure 6.20).

Figure 6.19: Installation of SHW systems in social housing, Cubatao, Greater São Paulo.

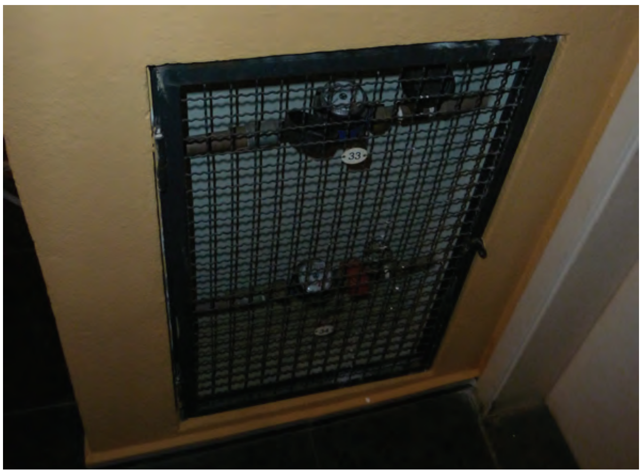


Figure 6.20: Individual water meters in social housing, São Paulo.

However, with the arrival of SHW systems the interface between individual water meters and solar water heating technologies has on occasions proved problematic. Such challenges have not occurred across the board. They are limited to specific instances and depend on the numerous possible variations in the material arrangements of metering and billing strategies used by the municipal water supply company, the variety of local water pressures, systems for interrupting service due to lack of payment, and technological configurations in the SHW system. Making solar energy through water requires the appropriate alignment amongst all these agents and processes. For example, interviews revealed cases where a triple reduction in water pressure (generated by water meters, cutoff valves for remote service suspension, and the SHW equipment) hindered domestic water flows, rendering SHW systems unusable. These cases, as an engineer at the CDHU pointed out, reflect the growing pains associated with implementing a new form of energy infrastructure. He provides the example of building typologies that were originally not designed for SHW, which need to be reconverted to allow for its integration: "these buildings were originally designed to have either one or the other system [SHW or water metering]. But then suddenly the CDHU start doing both of them… And at that point there is some incompatibility" (Interview P29).

Urban density and building typologies limiting the adoption of SHW

Urban densities and the limited maximum amount of dwellings that can be served by SHW systems in the context of high-rise living also impose a material resistance to SHW use. Here, water meters and the material alignments between water and energy infrastructures also play a role in establishing the limits of solar energy in the city. Given the preferred location of solar collectors on the roof terrace of buildings, there is only a finite number of dwellings in any one location that can be physically served with solar hot water. For example, the *Specification Guide for São Paulo's Solar Law* (ABRAVA, 2008) (Section 6.3.2) provides an example of a 16-story luxury residential tower with 64 flats, which requires a roof surface of 195m^2 for delivering 40% of the annual hot water needs (the minimum requirement according to São Paulo's Solar Law). If this is increased to 70% the required roof surface increases to 341m^2, a significantly large footprint for a building of these characteristics.

The number of flats that can be served by SHW can be increased with the use of collective systems (as opposed to individual SHW systems for each flat). But the use of collective systems requires an additional water meter at roof level, in order to monitor the amount of hot water that each flat is consuming and adjust billing accordingly. These are not conventional meters, as they need to operate with both cold and hot water. In the case of social housing, this added cost brings the use of collective SHW systems outside of the realm of possibilities for a housing mode that needs to be affordable by definition. As an engineer at the CDHU explains, "for each flat, we would need two meters: one for cold water and one for hot water. But that metering is expensive". He complements this statement by highlighting the difficulties of having two metering points and the reluctance of the water utility company to incorporate this into their operations: "the utility company would have to make two readings… There are problems associated with the duplication of the individualised metering" (Interview P27). This points to the extent to which the alignments required in the solar energy regime are material and socio technical, and involve technological objects as well as organizational practices.

Combined, these limitations impose a ceiling on the height of the social housing towers where SHW systems are installed. As a result, the CDHU decided to implement SHW only in residential towers of five or less stories. Yet the predominant building typologies of the CDHU in São Paulo's metropolitan regions are building towers of different heights, from 4 - 5 stories to 9 and above. In order to maximise land use and minimise the investment associated with land purchases, it is common for the CDHU to respond to housing shortages in highly urbanised areas through vertical development. High-rise social housing is more commonly present in the highly dense Greater São Paulo, characterised by high land prices alongside the greatest housing shortage within the State. High urban densities and residential towers, as the dominant building typology of the city, further challenge the use of SHW given the increase in (cold) water wastage due to the distance between the point of (solar) energy generation at roof level and its point of consumption in the bathroom. This points to a situation where sustainability achievements in energy could imply less sustainable forms of water consumption (see Section 7.4.2). In assembling local energy, failure is not exclusive to the process of forging alignments. Thane's experience, examined in the next section, shows how failure is more common in the context of coercive power, particularly when implemented in the absence of governmental techniques.

6.5 Confronting failure: resisting the local governance of energy

Governing is always an attempt; a utopian desire; an intent plagued with failures (Li, 2007b). The local governance of energy encounters resistance, challenge and refusal in a multiplicity of human and material ways. This final section examines a particular form of failure: the human resistance to 'solar laws' and thus the limited agency of coercive (non-governmental) techniques. Both São Paulo and Thane have passed local laws making the use of SHW mandatory for new construction (Section 4.3.1). In both cases, municipal officers argue that the main motivation for the Solar Law is the need to address environmental issues as well as respond to climate change and energy constraints. Solar laws share with standards and calculation techniques an attempt to codify objectives. However, rather than governmental techniques, they represent a sovereign power at play. Acting alongside a variety of governmental techniques, they are an example of the multiplicity of power modes operating in tandem within governmentality (Foucault, 2009: 107; see Section 6.2.1). Solar laws in both cities have played a significant role in promoting solar business locally, and thus consolidating and potentialising the solar energy regime. Yet, rolling out the local governance of energy through sovereign power brings about a tension between coercion and governing. It is argued that the coercive power of the law on its own is limited, and that the success or failure of solar laws is related to the way in which non-governmental and governmental techniques work in tandem.

6.5.1 Beyond governmentality: codifying energy objectives into local law

Thane was one of the first Indian cities to enact a law making the use of SHW mandatory. According to the city's Municipal Commissioner, R. A. Rajeev, the primary motivation behind the law was an interest in strengthening the city's environmental credentials: "It's [because of] the overall responsibility towards a sustainable city [that] we've taken up this decision" (Interview P10). The central Indian government had already recommended to local governments the use of solar laws, although very few cities have implemented it. Thane became an exception in this regard, not only by passing the law, but also by linking it to the local planning codes and enforcing it through well-established building approval processes. New constructions do not get the final Occupation Certificate until an officer designated by the Executive Engineer of the city's Town Planning Department has visited the property and performed a visual inspection confirming the presence of the SHW system, amongst a multiplicity of other planning requirements.

For the municipality, according to the Director of Thane's Electrical Engineering Department, enforcement of the Solar Law via the local planning code has been "a very concrete step taken for renewable energy" (Interview P11). The municipality credits the Solar Law with the significant increase in SHW that occurred between 2005 and 2010:

> *Whatever you can see in Thane today, it is mainly because of mandatory rules. [This is] because without [SHW] we are not giving*

any certifications for occupation and it is a mandatory thing that everybody has to implement. There is no choice (Interview P11).

In effect, Thane's growing urban landscape is distinguished by its extensive use of solar hot water systems on roofs (Figure 6.21). The municipality estimates that between 2005 and 2010 over 715,000 lt/day of solar hot water were installed, mostly through private installations (Thane Municipal Corporation, 2010).

Figure 6.21: Urban growth and SHW, Thane.

Through the codification of energy objectives into legal codes of local value, enforced through a set of procedures aimed at obtaining local government approvals, the city receives energy as a new subject of regulation. Framed by an ethos around urban growth, the local regulation of energy makes its way alongside plot densities, floor area ratios, structural integrities of buildings, provisions for water circulation, parking standards and innumerable other items to be governed by local building codes. The code's ability to achieve governing objectives by the sheer coercive power of the law is mobilised through the enforcement provisions of the local planning system. Yet Thane's Solar Law fails to deliver on its own.

6.5.2 The limited agency of non-governmental power: the breakdown of Thane's Solar Law

In its implementation, the sovereign and coercive power of the solar energy regime falls short, requiring governmentality, that is, a broader set of techniques aimed at conducting conducts and ruling through freedom. In Thane, despite the presence of an enforcement mechanism – as well as claimed success – in forcing housing developers to install SHW systems, the Solar Law frequently results in the installation of undersized or low-quality systems. The planning procedure associated with the enforcement previously described, which through visual inspection confirms the presence or absence of SHW, does not account for issues of quality or capacity in the units installed. A former Assistant Director of Town Planning in Thane explains how, whilst compliance with the Solar Law is seen as one of the most important conditions within the planning process, staff members of the Planning Department lack the specific knowledge required to evaluate whether solar systems are appropriate for the building (Interview P14).

Distributors and manufacturers of SHW interviewed in Thane claim that housing developers, keen to minimise their financial burden, commission the cheapest systems available in the market. They also claim that developers choose to do business with SHW dealers based on how much the latter are willing to lower the price. These practices, they argue, inevitably draw quality down, leading to several distributors interviewed to express reservations about doing business with housing developers. As explained by one of them, "I am not doing business with new builders, because they are interested in cheaper, lower quality product, in which I am not interested" (Interview D1).

On the opposite side of the spectrum, the housing developers interviewed see SHW largely as an additional regulatory requirement imposed by the municipality with associated financial burdens for their business. During the period of public consultation leading to the adoption of the Solar Law, private housing developers in Thane (as in São Paulo) expressed concerns about it, arguing that the Solar Law would increase the capital expenditure associated with property development. Now that the law is in operation, SHW is not seen as the main water heating technology of the dwelling but as a secondary system. Despite the provision of SHW systems, flats come fitted with small electric boilers in each bathroom. When they are not provided, it is expected that users will install them in the future. Therefore, provision is made for electric boilers in the form of space and electricity connection. SHW does not figure in the building's marketing material and there is a general distrust about its ability to provide for the user's hot water needs, fuelled by the inability of the systems to provide hot water during the monsoon season. This is summarised by a member of the housing development industry, who points to the reluctant nature by which developers are accepting the Solar Law:

> *Because of the mandatory policy, unfortunately people are not still in the mode of accepting that kind of thing [the SHW]. Because we require an amount of pain we need to give up. Because there are issues… since it is compulsory so builders are doing it. But builders are not willingly using it (Interview I1).*

Both in Brazil and India large manufacturers of SHW express their views against mandatory SHW policies. Instead of mandatory policies, operating though the sovereign power of the law, manufacturers interviewed would prefer a system that operates though freedom. In a strikingly governmental way, a representative of DASOL expresses his preference for the promotion of SHW systems through persuasion rather than regulation: "I'm not telling you to use solar [technologies] because the government forces to use solar. I'm telling you to use solar because it is better for you, it is better for the country, it is better for society" (Interview D18). In Thane, the local representative of a manufacturer based in Bangalore expresses similar thoughts, disapproving the mandatory approach because it results in low quality systems:

> *When it comes to the compulsion, when somebody is forcing you to put [a SHW system], …he'll always think of putting a cheaper system just to do the paperwork… he'll go with the cheapest system and he'll take care this system should work for a year, up until when he has to maintain the building. [Then] he will go to another building. Now he will be least bothered about the quality of the system, the performance of the system after one year (Interview D5).*

The concerns of dealers and manufacturers in Thane are well founded, as evidenced by some of the projects visited over the course of the fieldwork.

Exemplifying the challenges of implementing SHW through the power of the law: Thane's Hiranandani Estate

Hiranandani Meadows and the Hiranandani Estate, the two largest urban developments in Thane (Figure 6.22), provide an example of how the mandatory provisions of the Solar Law in practice often fail to generate solar energy in the city. Both neighbourhoods, amongst the wealthiest in the city, were built by the Hiranandani Group, one of the largest development companies in India. They house approximately 5,000 families in over 75 high-rise towers (averaging 20 stories and above) constructed between 2000 and 2011. Hiranandani's plumbing engineers, the team responsible for SHW systems, express their appreciation of the Solar Law as a useful way to save energy. However, they also see the law as full of limitations. For them, SHW cannot fulfil the hot water requirements of the users due to the limited roof space associated with high-rise buildings. The company's signature architecture, based on tilted roofs resembling classic architectural styles, further limits the roof space available for SHW (Figure

Figures 6.22 and 6.23: Hiranandani Meadows, Thane.

6.23). The Solar Law recommends SHW systems with a capacity of 25 litres per person for residential uses (Municipal Corporation of the City of Thane, 2005), the standard recommended provision by the city's distributors of SHW systems.[15] Yet, Hiranandani provides only 25 litres per flat. When discussing the use of SHW systems, Hiranandani engineers emphasise the unavoidable provision of gas and electricity back-up systems for water heating purposes, as the solar system does not fulfil their hot water requirements:

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[15] The wording included in Thane's Solar Law (as per modification No. TPS/1203/205/CR-142/2004/UD-12 to the city's planning regulations) is not explicit in its requirement for solar systems in residential properties. The guidance of 25 litres/person appears in the context of residential uses such as hotels and hostels. The use of this figure as a guideline for all residential properties was confirmed by staff members of Thane's Electric Engineering Department during research interviews.

> *Yes, [the SHW system] is actually useful, to save the energy; it is like power. Actually, we are putting [electrical] boiler backup also. [The boiler] requires very minimal time [to heat the water]. The solar system does not fulfil our whole system requirement… that is why we have to put another backup of electrical boiler also (Interview I3).*

With between 4 and 6 flats per story and an average occupation of 4 to 5 people/flat, the Hiranandani projects visited provide significantly undersized SHW systems for the number of apartments in each tower (see Figure 6.24, documenting a 27 story tower with 104 flats and a SHW system providing 25 litres/flat via 22 collectors and two water tanks with a capacity of 1,300 litres each). In practice, this, along with the long distance that the water needs to travel between roof and bathroom (Section 7.4.2), renders the systems unusable. Whilst developers fulfil their legal obligation of providing SHW systems for their apartments, residents in the Hiranandani Estate complain about the lack of performance of the SHW systems provided. On occasions, they are not even aware that their tower has SHW, and, from the day they moved in, they have been relying on electric boilers. As two residents of the Hiranandani Estate explain, the systems are hardly used:

> *I think we just used it once in the past five years. We thought one day "today we are going to use it", so me and my brother thought that we were going to use the SHW. The problem was that we had to put the tap on for a long time for the hot water to come. So it is a wastage of water… The system worked after putting the tap on for 15 minutes. Then we got warm water... Trust me; half of the people don't even know that there is a solar hot water system up there (Interview U6).*

> *…[residents] believe that, okay, we have the system, but to what extent they use it is something doubtful… Largely they use the electric water heaters…. [there are] at least 196 flats [that] are 90% occupied. So I believe that this solar system cannot serve all… I don't think it is sufficient (Interview U16).*

These quotes show how a combination of factors affects the final use of SHW systems. These range from lack of knowledge about the systems to the physical distance that water needs to travel before reaching the point of use. However, there is a consistent message regarding the limited size of the systems installed in relation to the amount of population they need to serve. In the face of the initial failures, SHW systems have a 'precarious existence'. Once the user fails to succeed in obtaining solar hot water during the early days of the flat's habitation, the family quickly solves the everyday problem of heating water through traditional means (electricity) and the SWH system is rapidly forgotten.

Figures 6.24: SHW at the Gemini Tower (Hiranandani Meadows). The system is composed of 2 tanks and 11 collectors per tank. With 1,300 litres per tank, the system provides 2,600 litres of hot water every day. The tower has 27 stories and 104 flats. The system provides 25 litres per flat.

In embracing governmental over sovereign modes of power, the municipality defends the Solar Law by claiming "the rules are drafted as a catalyst only" (Interview P11). Yet here the agency of such 'catalyst' failed to deliver on its own. What was missing? Through governmental techniques, Thane *calculated* and made energy visible energy, but did not *standardise* it (Section 6.3.1). In São Paulo, standardisation – not so much an initiative of the state, but one carried out by non-state agents – played a key role in controlling quality, capacity and performance, the key issues standing in the way of Thane's local governance of energy (Section 6.3.2). The case of Thane's Solar Law provides an example of the tensions between coercive and governmental power. Its failure in resolving critical issues, such as the level and nature of consumption of hot water and the available urban space for solar technologies, introduces a debate around possible and necessary steps to move from a mandatory to a more governmental approach within the broader local governance of energy. However, bypassing resistance in the solar energy regime through a governmental approach requires not only performance techniques, as discussed in this chapter, but also an engagement with the user and its identity though techniques of agency (Chapter 7).

6.6 Conclusions

The arrival of the city as a space from where energy is governed, coupled with the rise of decentralised renewable technologies such as SHW systems, marks a significant change in the way electricity systems in the city operate. The proper functioning and delivery of the large-scale centralised networks increasingly relies on the support of decentralised and territorially dispersed strategies, which is to say, a new geography of energy in which the city is the locus. This change implies a reconfiguration of the spaces for governing energy, signalling a reterritorialisation of energy dynamics: energy becomes an urban process, generated from within the city, assembled through a multiplicity of human and material agencies scattered across the city, and governed through governmental techniques that emanate from local stakeholders.

Thane and São Paulo embarked on this process in very different ways, and through different governmental techniques, partly as a function of the key stakeholders involved in the governing efforts. In attempting to govern energy in the city, Thane, following a municipally led strategy, relied primarily on calculative techniques. The baselines, masterplans and targets devised for this purpose made local energy visible, constructed energy as a local object in need of governing, and enabled action in the future. They set out specific strategies for intervention, establishing a way to become 'low carbon' through exemplar projects, and signposted possible paths. They also identified risks, seen as the agencies likely to derail the journey, and suggested ways for dealing with them. Finally, they embedded means to establish scalar dialogues with other agencies outside local government (such as central governments or the final user), capable of offering a much-needed support for the achievement of the objective. Yet, calculative techniques restricted the intervention to the domains of energy and electricity, failing to account for the multiple material relationships involved in making energy locally, and thus, failing to forge the much-needed alignments between water, energy and a broad set of other materials required in order to make local energy out of the sun.

In contrast, São Paulo, following an industry-led strategy, relied on techniques of standardisation. Both knowledge and materials were standardised through an active involvement of the private sector and the work of the state at different scales. Standards established boundaries between incumbent and newcomers as well as mainstream vs. alternative strategies, regulating and controlling the emerging market of solar energy. They also captured the materiality of the solar energy regime, providing an approach to local energy that embeds a greater integration with material flows and qualities as well as other resources – such as water. This integration proved essential for the success of the strategy. Knowledge standards played an important role in forging the alignments needed within the world of plumbing and building hydraulics, securing that those involved in making energy locally – engineers, builders, architects, dealers, manufacturers and installers – possessed the appropriate knowledge for the job. Material standards proved key for governing material qualities. Together, they ensured the quality and reputation of SHW systems, advancing the local governance of energy.

Both in Thane and in São Paulo, establishing the solar energy regime involved forging socio-material alignments between the city and its water and energy infrastructure networks. Failings in these alignments illustrate how the regime is a work in progress, operating as an unstable, fragile and prone to failure assemblage. The urban nature of the city, with its tall towers and high densities, puts material limitations on the regime, drawing its boundaries. Such boundaries are reinforced by the problematic interfaces between water and energy infrastructures (in the form of SHW). Here, the linkages between ways of metering water consumption and ways of metering energy consumption (in the form of hot water) are an example of the growing pains associated with transforming energy regimes in the city. The challenges of this interface are not only material (e.g. aligning water meters and SHW), but also organisational, as they involve the practices of the agencies in charge of managing resources in the city (e.g. aligning the billing practices of water utility companies and SHW). Failing and learning how to manage such failures is essential for regime consolidation.

Finally, establishing the solar energy regime is not only about governmental modes of power. In both Thane and São Paulo, the solar energy regime combines governmental and sovereign modes of power, via a simultaneous use of governmental techniques and solar laws. In Thane, the solar law is enforced through the local planning system. However, such system, driven by an urban growth ethos and managed by urban professionals, does not account for issues of quality and capacity within the SHW system. This specialised energy knowledge falls outside the expertise of the urban planner. The result is a variable rate of success, where several of the systems installed are undersized or of low quality. In the practical absence of governmental techniques such as standards aimed at maintaining minimum qualities and capacities, the coercive power of the law falls short. Success lies in the appropriate integration of different modes of power.

The use of an analytics of governmentality, with its emphasis on the techniques and practices required for governing and assembling energy locally, provides an innovative way of pursuing energy research. This form of energy social science generates useful entry points for simultaneously considering the social and material dynamics involved in the practices of energy production. It is an approach that explicitly recognises the ways in which the material and social dimensions of energy are co-constitutive of each other. Energy is revealed relationally and in the context of the integration with and consideration of other resources such as water.

Chapter 7

Imagining solar subjects: Reconfiguring energy identities

7.1 Introduction

This final chapter analyses the ways in which the subject is imagined and configured within the solar energy regime: how policy makers and system designers imagine users and their practices of energy (and water) consumption. It examines how the solar subject is "progressively constituted, symbolically and practically, through specific points of purchase" (Allen, 2011: 73). Here, the identity formation dimension of governmentality (see Tables 3.1 and 3.2) is at play, shaping the ways of conceiving the people to be governed, their statuses, capacities, desires and the form of their agency (Legg, 2007b; Dean, 2010). Identity formation in the solar energy regime operates via "multiple techniques of self-esteem, of empowerment and of consultation and negotiation" (Dean, 2010: 196). It also functions through the reconfiguration of the identities of energy consumers and the redefinition of the relationship between urban infrastructure and users.

Within governmentality, notions of identity and citizenship, where governing recognises a form of 'civic virtue' and attempts to shape the qualities and dispositions of the governed (Kymlicka, 2002), are recognised as important ways through which the conduct of the self and of others is conducted. Constituting environmental subjects is one of the key ways by which the governing efforts around sustainability operate (Agrawal, 2005). When applied to the realm of energy, new energy subjects are created and fostered (Walker et al., 2010). In

Thane and São Paulo, there are three ways in which energy subjectivities are shaped within the problematic established by the rationalities constituting the solar energy regime. First, through shaping identities via notions of citizenship (involving rights and duties), public awareness on energy issues, and public participation mechanisms around energy decisions; second, by reconfiguring the position and role of the subject in relation to infrastructure, where consumers are seen as producers and the subject itself becomes a constitutive part of the infrastructure; and third, by regulating practices around energy consumption via (hot) water use.

Imagining the solar subject is not an apolitical exercise. It implies the adoption of principles and ideas orienting tasks and priorities. This ethos of governmentality has implications for issues of inclusion, exclusion and resource distribution. Given the social demographics of Thane and São Paulo, a key aspect of the transformation of energy infrastructures in each city is the extent to which these efforts affect issues of social justice. Inquiring about the energy user leads to a discussion around who is included and excluded from these emerging renewable energy practices, turning the initial question on its head: how is solar energy imagined in relation to the subject? What purposes stand at the foundations of such new forms of energy? In tackling these questions, the chapter finishes with a brief discussion of the ways by which solar energy is mobilised – or not – in the context of social justice and urban inequality.

In analysing the mobilisation of urban infrastructure for a variety of purposes, where social and market rationales interact and compete in a variety of ways and through a variety of political logics, this chapter illustrates a form of energy research that considers the subject in its political dimension. This is achieved by considering not only how the subject interacts with or is configured by infrastructure, but also what infrastructure is for and who benefits from it. In this way, drawing from urban scholars who have pointed to the politics of urban infrastructure (McFarlane and Rutherford, 2008; Bakker, 2003; Graham and Marvin, 2001: 7-29; see Section 3.2), this chapter proposes a comparative energy social science that is decidedly political, opening opportunities for future research drawing on the work carried out during the course of the thesis.

Following this introduction, Section 7.2 introduces a variety of key analytical concepts around the constitution of the solar user, particularly around the configuration of resource bound identities and citizen differentiation. This is followed by Section 7.3, where specific awareness and participation mechanisms aimed at shaping the emerging energy identities in the city are discussed. Section 7.4 focuses on two specific ways of imagining the user-infrastructure interface in the context of SHW: through self-sufficient energy producers and regulated water consumers. Finally, Section 7.5 provides a discussion around who gets to be the new energy citizen and how this is a process of subjectification framed by contrasting modes of urban politics.

7.2 Energy in the context of identity formation and the constitution of social differentiation

Governing through freedom requires constituting the very subjects that are being governed. The solar energy regime is constituted not only by a set of governmental rationalities (Chapter 5) which are operationalised through governmental techniques (Chapter 6), but also by specific subjectivities (this chapter). Such subjectivities are understood as the imagined (and thus ideal) identities necessary for the governing efforts to achieve success. This implies "an epistemological conception of the people to be governed" (Legg, 2007a: 12). Forming subjects as a mechanism for conducting conducts is carried out by all stakeholders involved in governing. As a governmental mechanism, it relies on aligning the objectives of the governed with those of the governor, thus relies on the freedom of the subject (Chapter 3).

This section examines, from a conceptual perspective, how the solar energy regime involves a new set of energy identities that embody positions concerning the environment, resources and infrastructures. It also examines the implications of transforming the subject's position in relation to infrastructure, transforming subjects from consumers to producers and 'prosumers'. Both processes of constituting subjects endow the governing efforts with values, principles and a sense of orientation – the ethos of governmentality. Drawing on this, and building on the study of post-colonial governmentalities, the section closes by discussing a different way of thinking about the energy-subject relationship, examining how rationalities that underpin inequality and differentiation, or that promote social justice and integration, are embedded in the act of imagining the solar subject.

7.2.1 Constituting environmental subjects

Section 3.4.3 discussed the role of subjectivities in governmental modes of power. Here this same notion is discussed in the specific context of environmental governance. Environmental dynamics have provided fertile ground for an analysis of how notions of citizenship and identity play a role in the context of governmental programmes (Leffers and Ballamingie, 2013; Dowling, 2010; Rutherford, 2007). For example, Rutland and Aylett (2008: 642) analysed the ways by which municipal governments attempted to shape citizens' identities as part of climate mitigation strategies through "the creation of a responsible, carbon-calculating individual". Similarly, Oels (2005) evaluated the privileged role of partnerships in the governing of climate change, arguing that responsibility for climate change is passed on to non-state actors who embrace the issue as a 'matter of concern'. Here power relies on productive rather than restrictive forms of operation (Section 3.3.1), empowering citizens to do certain things and not others, yet operating in ways that are not strictly liberating, neutral or directionless (Rutland and Aylett, 2008). If governmentality means a redefinition of governing as a calculative activity (Chapter 5), it also means redefining the subject as a calculative subject willing to embrace forms of environmental calculation (Paterson and Stripple, 2010). Overall, new forms of rationality are fostered in subjects, with individuals and organisations required to measure their experience in terms of, for example, costs and benefits, financial gains and losses and productivity maximisation (Rose, 1999: 152; see also Rankin, 2001).

An analytics of governmentality reveals how subject formation lies at the confluence between imagination, subjectivity, institutions and power/knowledge (Agrawal, 2005: 222). Such 'environmentality' points to how, for environmental rationalities to operate, a more active role of local stakeholders is required. In this way, governing creates environmental subjects (e.g. individuals and communities sharing perceptions of environmental scarcity and in agreement with environmental objectives) as much as the very objects of environmental concern (e.g. energy, forests, etc.) (Agrawal, 2005). It is a process that aligns the governmental rationalities at play with the specific objectives of the subject. In the case of the local governance of energy, the problematisation of energy through rationalities around resource constraints, climate change and energy demand creates particular subject positions that find an expression in resource, environmental and energy aware individuals. Governing relies on affecting the subjectivity of consuming individuals and creating empowered (dutiful and rightful) energy citizens, often endowed with specific forms of agency in relation to urban infrastructure. Outside governmentality literature, Devine-Wright has used notions of energy citizenship in the context of decentralised renewable technologies to describe an understanding of the public as an active stakeholder within discussions on energy futures. In his analysis, notions of energy citizenship involve the recognition of energy as a social necessity, where the central values are related to issues of equity and justice. He argues that these notions are more likely to emerge from decentralised technologies, where greater levels of public involvement are required, standing in opposition to the passive and detached notions of the 'energy-public' emerging from traditional centralised energy systems (Devine-Wright, 2007).

Such creation of resource-bound identities is rolled out through specific procedures, practices and mechanisms aimed at involving the public in energy initiatives. Through techniques of government, subjectification normalises and renders certain subjectivities visible and intelligible (e.g. consumers vs. producers), whilst unnaturalising and occluding others (e.g. middle class vs. poor) (Butler, 1996, cited in Rutherford, 2007: 301). A governmentality analysis is useful for unpacking the techniques involved in the functioning of this mechanism, highlighting the desired need for shaping "citizens with a certain mode of self-reflection and certain civilised techniques of self-government" (Rose et al., 2006: 97).

7.2.2 New subject configurations in the world of infrastructure

By their very nature, by locating energy generation equipment within the domain of the home, domestic SHW systems provide energy users with a more active role. SHW differs from other water heating technologies in that it endows users with possibilities for active engagements with urban infrastructures. With gas/electricity boilers and electric showers users play a more passive and receptive role within larger infrastructure networks in which the nodes of generation are located in distant locations. This is not a natural position, but one created in the making of a solution. In contrast, with SHW users cease to play passive and receptive roles, as opportunities for autonomy and control through ownership, maintenance, installation and, in some cases, manufacture open up. The user, now as the owner of energy equipment replacing part of their electricity or gas consumption, becomes a producer. In using SHW, the energy subject becomes a prosumer: one that is simultaneously producing and consuming. This new form of relationship with infrastructure can have significant effects in the subject's identity, as "the content that is presumed [solar energy] can signify the identity of the prosumer", signalling "a high degree of integration between the objects and subjects of prosumption" (Ritzer et al., 2012: 394).

Within the study of sustainable consumption, greater user involvement in urban infrastructures (Section 3.2.3) is seen as having various benefits, allowing real-time utility management thanks to "a close coupling of supply and demand" (Chappells and Shove, 2004: 140). Co-management, the joint ownership of renewable energy infrastructure between users and utility companies, has led to greater efficiency, better system operation, demand management opportunities and environmental innovation (van Vliet et al., 2005). Co-ownership, where the user shares the roles of producer and consumer, provides greater levels of appropriation of renewable technologies and increased awareness of environmental issues (Spaargaren, 2003). Finally, the integration of vernacular practices with urban infrastructures (e.g. the integration of traditional rainwater collection practices with municipal water systems) allows users to contribute to system functionality, giving birth to a new form of infrastructure that is more attuned to local climate and customs (Furlong, 2011). In the case of SHW, users are still consumers, as they need to acquire the SHW unit and consume the water and energy it produces. Yet, by playing an important role in smoothing the electricity demand curve (Chapter 5), SHW users become an important element in the co-management of the country's electricity infrastructure. They also put in place a type of infrastructure that is more attuned to local conditions, as it needs to incorporate local climate variability. Yet the use of SHW opens the possibility of other forms of engagement with infrastructure, as the possibility of manufacturing one's own SHW (the DIY SHW) reconfigures the user, making them into the infrastructure itself.

Examples of users directly engaging in the makeup of urban infrastructures challenge a common understanding of infrastructure as fixed, stable and static. Such examples also challenge the view of infrastructure as a non-dynamic material arrangement clearly separate from – and with little interaction with – the user (Furlong, 2010: 476). The new visibility of infrastructure networks and the direct engagement of the user produce an "active consciousness whereby users are purposefully engaged in the performance of the network" (Furlong, 2010: 477). The result is an infrastructure system where municipalities have opportunities "to work within their communities (and across scales) to develop systems that are more fitting with the needs of their locality and are yet flexible enough to evolve as needs change" (Furlong, 2010: 477). Different ways of engaging with energy users are likely to take infrastructure development along markedly different paths, shifting away from traditional 'predict and provide' models of infrastructure management by drawing attention to the logics driving demand (Evans et al., 1999). This points to how "technological outcomes [are] not inevitable and pre-ordained, but shaped by the array of different 'logics'" – or rationalities – at play (Devine-Wright, 2007: 65).

7.2.3 Reading the solar energy regime in the context of social justice

The rationalities that underpin the solar energy regime also guide the construction of the solar subject in relation to issues of social justice, integration, or differentiation in the city. Addressing the interface between processes of environmental subjectification, infrastructure transformation and social justice requires asking questions about who benefits and how the resulting configurations upset broader power relations and social structures in the city. This analysis is of particular relevance for cities such as Thane and São Paulo, where a significant percentage of the population live in conditions of poverty, in slums (or in *favelas* and *cortiços* in the case of São Paulo) and with limited (erratic and/or informal) access to electricity networks. This analysis concerns three of the dimensions of governmentality examined in Section 3.3, as it involves ways of thinking about the subject (episteme), the principles and orientation guiding action around such subject (ethos), and the decision to bring certain subjects to the background whilst foregrounding others (visibility). Examining the solar energy regime from this perspective highlights its political character, and opens a debate around the extent to which such a regime operates within – or bypasses – social agendas. The ways in which urban infrastructure scholars have acknowledged the specificity of the city in the South was examined in Section 3.2.1, pointing to fragmented infrastructure provision and a service that has historically favoured the elites

(Kooy and Bakker, 2008; Jaglin, 2008; Gandy, 2006). In this section, this is done by drawing on Indian and Latin American authors who have used governmentality to understand the role of elites in shaping governmental techniques in their favour (in the case of India; Chatterjee, 2004) and to unpack the role of the neoliberal state in creating the poor as a domain for governing (in the case of Latin America; Giavedoni, 2012).

In the case of India, Chatterjee pairs 'civil society' with the country's modern elites, "walled up within enclaves of civic freedom and rational law" (Chatterjee 2004: 4). Drawing on a colonial past where a concern about population (by the British Raj) came before the recognition of sovereignty and citizenship, Chatterjee identifies an absence of civil society as a true space of citizenship. Instead, he speaks of a political society, tenuously right-bearing citizens that "have to be looked after and controlled by various governmental agencies" (Chatterjee, 2004: 38). Whilst the Indian civil society is limited to a relatively small and easily located middle-upper class representing 'the high ground of modernity' and in a position to claim civil rights, the majority of the population live as disenfranchised political subjects struggling to access the services provided by the infrastructures of the state (Chatterjee, 2004). Whether the emerging decentralised infrastructures of the solar energy regime are provided in the spaces of the civil society identified by Chatterjee, or in those of the political society where the majority of urban India is located, matters for social justice as much as for the legitimacy of the very notions of sustainability enacted by the particular governmental rationalities framing the solar energy regime.

In the case of Latin America, the use of an analytics of governmentality has enabled a change in the dominant conceptualisation of the state, away from notions of 'the state in crisis' where social problems are explained by a weak, absent, dysfunctional and corrupt state (Giavedoni, 2012). The resulting 'critique of the state' is an examination of the role of the state in the definition and constitution of social problems. Under this analysis, poverty, far from being an always-present problem resulting from state weaknesses, is a recent object created through governmental techniques (such as censuses, statistics, and, in the case of electricity, social tariffs). It emerges with the decline of the welfare state, which throughout the 20th century was concerned with the universalisation of services, and the late 20th century adoption of a neoliberal state that limits its social provision to assisting 'deprived' subjects with the aim of granting minimum biological requirements (Giavedoni, 2012: 100; Alvarez Leguizamón, 2008). In this context, Giavedoni sees governmental technologies to secure energy services for the poor (e.g. social tariffs which, through censuses recording income levels, regulate who has access to cheap energy and other social services and who does not) not only as a form of energy governance, but also as a way of "governing popular sectors of society through services for energy provision" (2011: 57, translated from the Spanish).

This leads to questions over the manner in which the solar energy regime in São Paulo and Thane is constructing the low-income subject, and around the broader societal purposes assigned to solar energy within this regime. Is the solar regime aimed at one particular sector of the population whilst excluding another? Is this new form of urban infrastructure enmeshed in old systems of exclusion and domination? In the case of São Paulo, where various SHW programmes operate directly in the context of social agendas, how is such energy provision operating as a tool to govern beneficiaries of social housing? To benefit them? Under which broad rationalities (e.g. neoliberal perspectives that make the subject into a consumer of infrastructure vs. more universalising perspectives aimed at providing infrastructure access regardless of income level)? What type of subject is constituted by these broad rationalities and how does the subject respond to this attempt to construct its identity? Not all of these questions are answered in this chapter, as they would require an entire PhD in their own right. However, in the spirit of raising questions and opening avenues for future research, the final section of the chapter (Section 7.5) provides an initial discussion around these topics, and briefly examines how the solar energy regime in both cities approach issues of social justice.

7.3 Energy identities

This section focuses on the process of shaping environmental identities in the solar energy regime through the rollout of strategies for awareness and participation in energy issues, leading to an attempt to create resource-bound identities along the lines of an 'energy citizenship' (Devine-Wright, 2007). Over the course of the fieldwork, this technique was present in different intensities in both Thane and São Paulo. Here, it is examined through the case study of Thane (for an example from São Paulo, where standards are used to shape identities by pointing to the links between SHW, environmental stewardship, water consumption, energy demand and citizenship responsibility, see Section 6.3.2). In Thane, the example focuses on public involvement initiatives within Thane's Solar Cities Programme. This occurs first through the creation of a 'Solar City Stakeholders Committee' as a channel for public participation aimed at influencing the development of the programme; and secondly through the development of specific initiatives to generate awareness of energy issues through a public information centre for renewable energy known as the Solar City Cell. Through these two mechanisms, this section details how in Thane stakeholders involved in rolling out energy initiatives conceive expected forms of energy conduct and construct a set of energy related duties and rights.

7.3.1 The municipality as the appropriate place for energy intervention

When asked about the biggest challenge for the broader adoption of SHW systems in Thane, the city's Commissioner points to citizen awareness: "Certainly there has to be a high level of awareness generation among citizens about this programme" (Interview P10). The municipality sees itself in a privileged position to take action on this front, due to its proximity and access to local groups and, more explicitly, energy consumers. This is exemplified by an interview with a former Municipal Commissioner of Thane, involved in the early days of the Solar

Law. He explains how local governments are in a better position than regional or centrally based stakeholders – such as energy companies – for engaging the final user in energy initiatives: “the [Municipal] Corporation offers a very sound platform, a common platform for all the stakeholders coming together…we were in a good position and we were well placed to play a central and coordinating role” (Interview P9). In his view, the municipality provides a space where suppliers, distributors and, above all, users can meet to find alternatives towards energy conservation, and a good platform for the national government to implement its energy programmes:

> *Normally these kinds of initiatives for energy conservation and cogeneration …could have been done by the electric supply company or the distribution company but their access to the people and different stakeholders is constrained, unlike us …We have the people's representative bodies and through them we interact with different groups…. [so it is] in the larger interest of the city, and we spread this message through people's representatives. So we were in a far better position (Interview P9)*

For the staff member in charge of energy projects in Thane, municipal involvement in energy initiatives is key: “if they [municipalities] are involved definitely it will be a success” (Interview P11). In his view, success is the result of the Municipal Corporation being an elected body, and what he sees as the resulting ability of such authority to govern the conduct of the population due to proximity: “Those people [local councillors and staff members of the municipality] understand the pulse of the public. They can influence the public” (Interview P11). In a similar fashion, in the city of Guarulhos in the São Paulo Metropolitan Region, the officer in charge of local energy initiatives, argues that municipalities have an opportunity to engage the user significantly beyond the ability of the national government to do it. Municipalities, thus, can contribute by providing a perspective where the emphasis lies on issues of demand and consumption rather than supply and provision. Following this argument, he establishes a broad vision and remit for the municipality's involvement in energy issues, while criticising other municipalities that fail to embrace such a vision:

> *What we want is, in addition to what the federal and state level governments are doing (who are always thinking about energy provision) for municipalities to take action with regards to the rationalisation of that energy… We think that municipalities are key for this, because families, industry and commerce are not at the federal level; they are here, in the municipalities. It is here where they exist; here where they live; here where they enjoy, or not, their quality of life; here where they produce...*
>
> *However, many municipalities think that energy interventions are a matter of the federal government. A country where the municipalities do not have [an energy] approach is a country that is losing (Interview P23).*

This quote suggests that municipalities engaged in local energy initiatives justify their intervention in their ability to conduct energy conducts, an activity enabled by geographical proximity and reach. Power, "always already spatial" (Allen, 2011: 151), operates here through the ability of authority to enable trust relations thanks to proximity (Allen, 2011: 149). In so doing creates the impression of a better alignment of its objectives with those of the governed. A common claim for the novelty of this approach is a change of focus, where the emphasis of the governance of energy does not lie on issues of supply but of demand, putting in place an energy regime in clear contrast with the centralised regime described in Chapter 2. From the perspective of the local authority, this change of focus is achieved through initiatives for energy awareness and the development of spaces for public participation around the topic.

7.3.2 Governing energy conducts through identities

In Thane, two mechanisms involving local stakeholders and the public play a central role in the solar energy regime: public information centres aimed at disseminating (solar) energy knowledge and forums for public participation in the development of local energy strategies. These techniques are intended to create individuals that are aware of energy issues and committed to the objectives of energy efficiency and conservation. They also allow for local input in the roll out of the strategies for the promotion of renewable technologies in the city.

Solar technologies in India: constructing energy identities with a social conscience?

The idea that solar technologies should be used to create both moral precepts and national duties – an ethical consideration within governmentality – emerges as a common feature of the stakeholders interviewed in Thane. This consideration combines national and environmental identities, where the use of SHW systems is good for both 'nation and planet'. It justifies energy actions by combining environmental drivers with a citizen response to the country's precarious electricity situation. The MNRE's director of India's Solar Cities Programme illustrates this approach when, in promoting the use of SHW systems amongst the public, he argues that there is a need to save both city and nation from pollution whilst "improving the nation's environment":

> *… Do you know how we motivate them? When I go to the meetings I tell them "if you install a solar water heating system you are contributing to saving your city or ultimately your nation from pollution, so this is your contribution; don't say that you are spending money or something; if you're spending money, you are spending money for your nation towards improving its environment". These are the things that we have to motivate people (Interview P1).*

This quote indicates an attempt to create an environmentally aware citizen who is also an energy aware citizen. Here, environmental and energy identities collude with national identities for the mobilisation of the citizen into action. These energy subjectivities are brought into being by members of the solar assemblage as part of their own identity as well as that of the users they imagine. For example, one of the owners of a SHW shop in Thane refers to his social and citizen motivations when explaining the history of his business: "We were looking for a business, but one that in a way, should help the people and the nation also… so we went for renewable energy" (Interview D3). Similarly, a dealer of SHW systems, aware of the perceived social and environmental value of his business, explains how:

> *I have taken solar [energy] as a business for earning purposes and for social purposes also. Because while earning, I am doing [something] social for [the] Earth, for society… by considering global warming, by considering eco-friendly business... And there is an energy crisis… a shortfall of coal… and there is a future for these solar [technologies] (Interview D1).*

This quote illustrates how the governmental rationalities of the solar energy regime are mobilised towards shaping identities. Here an energy subject who plays an active role within the regime invokes both climate change and resource constraints rationalities, claiming a commitment towards social and environmental positions whilst addressing the country's energy crisis. In a similar way, a visitor to Nagpur's Renewable Energy and Energy Efficiency Resource Centre, writing on India's Independence Day in the Centre's visitor's book, expresses a viewpoint that links energy interventions and a feeling of national belonging: "I want to feel better to do something for our nation" (Figure 7.1). This visitor centre provided the model for Thane's Solar City Cell, which is discussed in the following paragraphs.

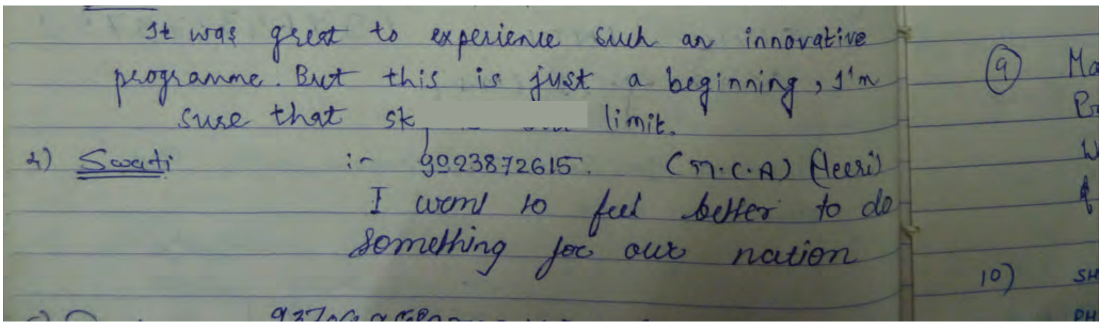

Figure 7.1: Connections between national and energy identities - visitors book at Nagpur's Renewable Energy and Energy Efficiency Resource Center (REEERC).

An energy aware individual: the Solar City Cell

Since the adoption of the Solar Law, the Thane Municipal Corporation has carried out public engagement activities on energy issues. For example, awareness programmes have been carried out at housing complexes, commercial complexes, and hospitals, "to educate citizens about the benefits of non-conventional power" (Thane Municipal Corporation, 2010: 25). These activities have included the display of SHW during special events at important local holidays, such as the 2008 Gudi Padawa procession, an annual event to celebrate the beginning of the New Year for Maharashtrians (Figure 7.2). More recently, the 2012 Gudi Padawa procession, with an estimated 25,000 spectators, was themed around the topic of energy conservation (Hindustan Times, 2012).

Figure 7.2: SHW on display during the Gudi Padawa Procession in Thane. The display includes a billboard with a photograph of the President of India awarding Thane a prize at the National Energy Conservation Awards of 2005 (Thane Municipal Corporation, 2010: 63).

As part of the Solar Cities Programme, Thane is implementing a Solar City Cell: a visitor's centre and technology demonstration space providing information on energy conservation and renewable technologies. This is the Solar

Cities Programme's attempt to engage with the final energy user, targeting both domestic and industrial consumers. The Solar City Cell has been modelled after Nagpur's Renewable Energy and Energy Efficiency Resource Centre (REEERC), an initiative of ICLEI's Local Renewables project (Figure 7.3). In Nagpur, this is a small office at the entrance of one of the main buildings within the Municipality's office complex, full of displays and catalogues on energy efficiency and SHW. The Executive Engineer in charge highlights the role of the centre in providing advice to citizens on issues of renewable technologies and educating them about solar energy:

> *If we propagate this knowledge to the people, through such centres, then people will be aware of this. If [the visitor] goes home with this idea …he'll drop down the energy consumption at his residence … energy centres [like] these can disperse this knowledge to the people, and make everybody aware of the renewable energy. That is why it is required. This is really a dispersion centre (Interview P18).*

Figure 7.3: Nagpur's Renewable Energy and Energy Efficiency Resource Center (REEERC).

In addition to receiving visitors, Nagpur's REEERC has organised exhibitions and activities in the different localities of the city, including workshops with school children. In the words of the REEERC's manager, "we want that the common people to come to learn about the different products and how they can use [them]". Nandkumar Jantre, Thane's former Municipal Commissioner involved in the early days of the city's Solar Cities Programme, explains how the city's Solar City Cell is expected to perform similar functions, "where the citizens can come there and experience these, read the literature and have a one window shop" (Interview P9). For the staff member in charge of local energy initiatives in Thane,

> *It'll be the nucleus for all the energy efficiency and renewable energy activities …whatever activities taking place within city limits will be originated from there …I'll be able to keep literature, audio-video mediums, demonstrations or knowledge dissemination lectures. I am [also] looking for [the] formation of energy clubs in schools. Every school we'll have energy club (Interview P11).*

This quote illustrates how subject creation is an essential element of Thane's solar energy regime. The establishment of the Solar City Cell illustrates governmental techniques around identity formation aimed at transforming the manner in which the public engages with energy. They operate through the generation of awareness and the distribution of energy knowledge, both at a specific selected site (the Solar City Cell) as well as across the city (in schools, processions and others). Energy is being re-territorialised in a multiplicity of ways, through drawing new boundaries between consumption and production, and involving a variety of sites and agencies across the city for the creation of new energy forms. Whilst the Solar City Cell is aimed at the public and focuses on the user, engaging "the citizen" in making solar energy in the city has also targeted specific local energy stakeholders. This is the case of the Solar City Stakeholder

Committee, the second mechanism for public participation within the Solar Cities Programme.

Local participation: the Solar City Stakeholder Committee

The Indian MNRE prioritises public engagement within the Solar Cities Programme. Its guidelines for Solar Cities suggest at least two stakeholder consultation events in addition to an inception workshop and other public activities (Government of India, 2008). The MNRE sees these events as important moments for members of the local community to provide input, propose solutions and get involved in the development of the Solar Cities Masterplan. At the offices of the MNRE in New Delhi, the Director of the MNRE's Solar Cities Programme describes public participation as a key forum where solutions are found and local stakeholders get involved in the process:

In various forums, they are discussing the masterplan preparation, the energy problem; then they are coming with the solutions, so they themselves are getting involved into the process ...So at least on average 4 to 5 meetings or interactions with the people, and they all are involved in the planning process, in the volunteering process… (Interview P1).

This quote suggests that instances for stakeholder participation are also intended to operate as mechanisms for involving the public in the problematisation of energy and in this way, in the process of translating rationalities into techniques. The Solar Cities Programme is conceived as a "people driven" initiative, where citizen's participation is a key objective beyond the achievement of the energy reduction targets established. In the words of the director of the Solar City Programme at ICLEI, "you can put a few megawatts power plant somewhere in the city and take power and make it green. Then you can achieve your 10% target. But this is not the purpose of the Solar City". Its purpose "is to involve more people in such a way that they can take part in the entire process and they can contribute to reduce carbon emissions, and using green energy, and using the energy more efficiently" (Interview P4).

In Thane, following the guidelines established by the MNRE, the municipality created a Solar City Stakeholders Committee for the purpose of stakeholder consultation, giving local stakeholders the right to contribute to the formulation of the 'solar city' concept and its local implementation. It works as an advisory board composed of selected members of the public as well as representatives of public and private organisations dealing with energy issues at local and regional levels. The committee operates with the active participation of the Maharashtra Chamber of Housing Industry, the Maharashtra Solar Manufacturers Association, the Maharashtra Energy Development Agency and other energy and environmental organisations, energy-related business and educational establishments. Participants were invited to attend meetings where drafts of the Solar City Masterplan were circulated and discussed, providing them with an opportunity to make comments, pose challenges or propose content. The forum has served as an open space for stakeholders to engage with issues of local energy production and consumption, discussing themes as varied as how to bring new technologies to the city or the possibility of gaining additional funds for financing solar activities through carbon credits.

In summary, two types of subjectivities are created by Thane's Solar Cities Programme. First, an environmentally aware citizen, who understands the national challenges around energy provision, knows about the benefit of solar technologies, and is willing to adopt them at home. Second, a collective subjectivity (via organisations) that participates in the translation of governmental rationalities into techniques, and in doing so, generates a greater sense of ownership of the regime. All the governmental rationalities examined in Chapter 5 (resource constraints, climate change and the problematisation of energy demand) are present in this process of creating identities.

7.4 Producing vs. consuming solar energy: different subject configurations

Perhaps the most governmental feature of the solar transformation of urban energy systems is the provision of a material ability for the subject to generate his/her own energy, making them into what Ritzer et al. (2012) have termed prosumers. Conceptually, this is akin to Otter's evaluation of liberal governments and their use of technology as a means for governing (2007; Section 3.5.1). Empirically, this was first highlighted in Chapter 5, when citing the words of the Director of the MNRE's of India's Solar Cities Programme, who asked citizens to "have [their] own house as a powerhouse" (Interview P1; Section 5.4.2). Yet solar subjects are not exclusively producers, as they are still seen as consumers of SHW systems as well as hot water. By proposing modes of urban infrastructure where the user is both producer and consumer, it is argued that the user becomes a constituent part of the urban infrastructure, fostering a new practice of energy production. However, by interacting with SHW, the user as a consumer also becomes governed (or governable) through regulations around (hot) water consumption.

This section examines the possibilities and implications associated with fostering two contrasting types of subjectivities through SHW. First, when the user is imagined as an energy producer, through a form of knowledge and technological arrangement that enables users to manufacture their own SHW systems. Second, when the energy conducts of the user, conceived as a consumer, are regulated through the regulation of water conducts.

7.4.1 Becoming infrastructure: producing energy in the city

Whilst all SHW systems provide users with the ability to generate their own energy (by allowing them to own – and locate within their premises – the energy infrastructure) low-cost DIY SHW systems (Section 4.3.4) are particular in that they also encourage users to manufacture the infrastructure. This occurs outside of the field of operations defined by formal SHW standards (Section 6.3.2), as the standardisation process does not allow the user to manufacture their own generation system. Thus, by no means is this DIY form of SHW a common infrastructural configuration. DIY SHW systems (Figures 4.9 and 6.10) provide an exception that opens up new ways of imagining the solar user, visualising alternatives and opening progressive possibilities for a new set of agendas associated with urban infrastructures, from poverty alleviation to environmental awareness. It exemplifies a type of infrastructure that enhances the agency of the users, reimagines forms of infrastructure configuration, and supersedes an approach where users are seen primarily within the spaces of demand and consumption. In effect, the DIY SHW embeds users into the city's infrastructure networks and redefines the boundaries of infrastructure, reterritorialising energy by incorporating users as a constituent element.

In 1992, after years of working as a distributor of industrially manufactured SHW systems, Augustin Woelz started working on the development of low-cost DIY systems. His objective was to develop a technology that was more in tune with the economic and social realities of Brazil, and in this way to unleash the potential of SHW systems for providing cheap energy for the poor. Drawing on this governmental ethos, he founded the *Sociedade do Sol*, a non-profit organisation that adopted the objective of installing 1 million DIY SHW systems in Greater São Paulo. After 10 years of research and development, he designed a product capable of reaching water temperatures of between 45°C and 50°C. It follows simple assembly instructions and is based on cheap and easily available materials: PVC tubes, plaques and joints available in almost any hardware store.

Knowledge about how to manufacture a DIY SHW system is freely distributed over the phone, on the internet and in person by a network of volunteers holding regular workshops (Figure 7.4), making presentations in schools and community centres (Figure 7.5) and uploading videos on YouTube (Figure 7.6). As a member of the network explains, "it is a voluntary work. We don't earn anything from this. We get a lot of pleasure" (Interview P33). Those who participate in the

Figure 7.4: Training workshop on DIY SHW at the *Sociedade do Sol*, São Paulo.

Figure 7.5: Volunteers making a presentation on how to manufacture a DIY SHW system to adult learners at a school, São Paulo.

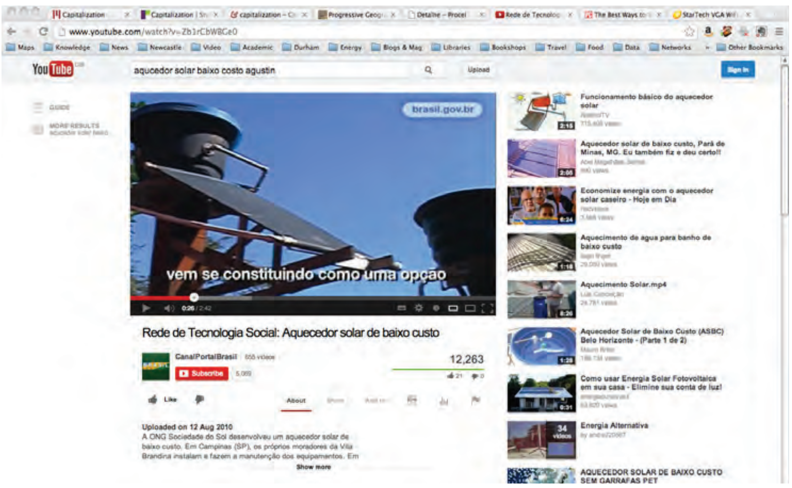

Figure 7.6: Internet (YouTube) videos on how to manufacture DIY SHW systems.

workshops of the *Sociedade do Sol* are encouraged to become 'monitors': loose affiliates of the organisation, with the responsibility of distributing the knowledge they gained at the workshop in the cities, neighbourhoods and communities in which they live. Moreover, if distributing this energy knowledge is a responsibility, accessing it is a right: "our work is… to accelerate the pace of spreading the word so that the poorest people start understanding that they have a right to a solar heater… they need to understand that they have the right to this knowledge" says Augustin (Interview P32).

Figure 7.7: Schoolchildren involved in a community project manufacturing DIY SHW systems, São Paulo.

Besides providing cheap energy, the DIY SHW system aims to be a social and educational project with the purpose of engaging the family in the manufacture and maintenance of the system. Through this involvement, the organisation seeks to create awareness and educate about energy and environmental issues (Figure 7.7). User involvement in product manufacture, and the resulting awareness on energy and environmental issues, is seen as the main difference between this DIY system and those that are industrially manufactured. Governmental rationalities around environmental problems and energy issues inform the construction of the subject (Dean, 2010), who is both an energy producer as well as an environmentally aware individual (Leffers and Bellamingie, 2013; Oels, 2005). This construction of the subject is a process that occurs through specific sociomaterial mechanisms, by relying on cheap and easily available materials, putting in place social networks responsible for disseminating knowledge around the systems, and engaging the family in the manufacturing process. In this way, infrastructure is informed by a rationality around social and environmental objectives, and outside commercial or market logics. In the words of Augustin,

> *… our process is different. Our process social. It is a process that involves [the user], where the family, the future owner of that house, is the one who has to install it. It is another perspective; not a commercial perspective… The factories are selling for those who already have houses; not for social projects. The family should participate. It is an obligation. Otherwise, it is not a social project. The family has to be involved with the project, with the idea... And the seller should be working as a teacher. It is a teacher that is teaching the family how to manufacture the systems. Then, the family assumes the warranty; the family assumes the maintenance (Interview P32).*

The DIY SHW puts in place a progressive mode of infrastructure, which emphasises the ability of the user to access an energy generated by the user itself, highlighting notions of user independence. Infrastructure takes the form of knowledge transmission via social networks, and energy is seen in the context of subject rights (to solar energy) and duties (to transmit solar energy knowledge). The user is imagined as the foundational part of the energy provision system, yet also governed through it, as the obligation of becoming part of the urban infrastructure (through manufacture and maintenance) falls upon it (van Vliet et al., 2005). In line with accounts around prosumers and the implications of a greater engagement of the user in the performance of the infrastructure network (Ritzer, 2012; Furlong, 2010), the designers of the DIY SHW expect the user to have a greater identification with the solar energy regime as a result of this active involvement.

Re-imagining the energy user at the city scale

In Guarulhos, a city of 1.3 million people city located in the São Paulo Metropolitan Region, the municipal government is supporting the installation of low-cost DIY SHW systems through the so-called Guarulhos Solar Programme (Lei Nº 6713, de 1º de Julho de 2010). Its main promoter, Paulo de Tarso, the Director of the city's Lighting Department, would like to see 100,000 DIY SHW in the city. The main reasons he cities – rationalities and ways of thinking, or episteme – are the support of social agendas through energy technologies, the reconfiguration of energy subjects in the context of rights and responsibilities, and the mobilisation of local energy initiatives for supporting the local economy (Interview P23). In other words, the opportunities that low-cost technologies offer for supporting the poor, a belief in the philosophy of the right to (solar) energy, and the possible benefits that such initiative would bring to the city by relocating the public's energy expenditure away from private energy supply companies towards local expenditures. Through support for local initiatives around DIY SHW, the local government aims for energy to retain a social function – a governmental ethos –, making energy into an important element in the 'fight against poverty'. De Tarso promotes the ethos of the programme, endorsing the pro-poor values adopted by the Society of the Sun and establishing a separation between the DIY SHW and commercial approaches:

> *… it is a solution that comes out of the poor. Because when the Brazilian industry starts manufacturing solar heaters, what they want is to earn money. It is the natural logic of capitalism. I am not challenging that. But here, the idea of the Society of the Sun says the contrary. I am going to put technology at the service of society, first and foremost, and not at the benefit of private gain…*

> *In our programme there is an element of fighting against poverty, because a poor family who makes that investment, after one year they increased the value of the property, they increase their self-esteem, after one year they have already paid for the investment and there are*

> *going to get R$30 or 40 additional per month... You could use that to buy beans, rice... And what is even better, is money that is going to enter into the economy of Guarulhos (Interview P23).*

The governmental ambitions of the project are explicit: “What we are aiming to do is… that the municipality should achieve the role of interfering in the use of energy in society” (Interview P23). Here the subject’s right to energy is not exclusively about grid access, a common interpretation that builds on the ‘modern infrastructure ideal’ (Graham and Marvin, 2001), but about energy affordability via social technologies that lower energy costs: “It is not only about being connected to the electricity grid. The right is to have an electricity connection, but also to have the right to other equipment which brings energy, which I need in my home, and that the cost of obtaining that energy is accessible” (Interview P23). Such energy access is not achieved through state provision, but through the voluntary actions of thousands of citizens willing to ‘become infrastructure’ and manufacture their own SHW systems. Rather than access to energy, it is about “access to the means of energy production” (Interview P23).

Governmental techniques of calculation (Section 6.3.1) are also involved in the mobilisation of energy with a social ethos advocated by the Municipality of Guarulhos, revealing an economic ethos alongside the social. According to calculations by the municipality, 100,000 DIY SHW systems in Guarulhos would save 40 MW, the same amount of electricity generated by a small to mid-size power plant. Capital cost savings would be in the order of R$150 million (Brazilian Reais), whilst additional savings could be obtained due to the elimination of operational costs and transmission lines. In contrast, they estimate that installing 100,000 DIY SHW systems would require only R$60 million, with the majority of this sum coming from micro-investments by the families and business installing and using the systems. Each family or business would save in the order of R$360 per year on their electricity bill (~£100 British Pounds), enabling them to recover the investment in two years. In the view of the municipality, this also represents

R$36 million that would benefit the economy of local families and small business, and that could be re-invested in the local economy.

The Guarulhos Solar Programme illustrates how scaling up solar technologies involves a re-territorialisation of the energy problem (Section 3.6). Guarulhos has drawn ambitious – and difficult to achieve – plans for increasing the use of DIY SHW systems in the city. If such objectives were realised, SHW systems would generate the same amount of power than a small conventional power plant. The proposal of Guarulhos scales the idea of making consumers into producers to the city level, forcing a re-imagination of the role of users in the provision of energy services and opening possibilities for new configurations of urban infrastructure (van Vliet, 2004). Such alternative infrastructure configurations hold potential for better responding to local agendas, localising the financial flows associated with energy services and generating economic benefits for the city. They can also support locally specific social agendas, by contributing to greater equity in resource distribution and making energy services more affordable for the poor. This new energy arrangement upsets traditional power balances between central and local levels, opening possibilities for new scalar configurations and understandings of the role of the city in relation to the state (Brenner, 2001; Bulkeley, 2005). If re-configuring energy users into producers bring about a set of potential benefits, what happens when they are re-configured as water consumers?

7.4.2 Consuming solar energy: the joint regulation of water and energy access

In consuming solar energy, users are also imagined in particular ways. In the case of industrially manufactured SHW systems, most of the interviews and research instances in this thesis point to an understanding of the user as a consumer and client rather than a producer. Despite the user's ownership of the systems, and with the exception of the DIY system discussed in Section 7.4.1, acknowledgment of the user's role as energy producer is relatively restricted. The user periodically cleans the SHW unit, but, as seen in Chapter 6, involvement in manufacture and installation is limited by the knowledge associated with quality standards and the manufacturing processes. In contrast, in many instances the SHW user is seen as a consumer, although not always a consumer of energy but one of water. Using SHW implies a transformation of how water is consumed at home; its uses, times of usage and volumes might be transformed. Thus governing conducts within the solar energy regime entails governing water conducts, an intervention with implications for practices of water use as well as for the broader sustainability of the city.

Hot water: regulating times and uses

Several residents of residential towers interviewed in Thane commented on how with solar technologies "you can get free energy" (Interview U1) or "free [hot] water" (Interview U7). Yet, in practice, the provision of solar hot water is limited, as there is only so much sunlight available falling over the collectors over a 24-hour period. In contrast with electric showers, where there is no immediate restriction on the length of a shower, SHW demands new forms of regulation on the length of the shower, the amount of water used and the frequency of showering in order to ensure that all users have access to hot water.

In the case of collective SHW systems – such as the ones used in apartment buildings – some form of regulation is required for all dwellings to have a relatively fair and equal access to the system. São Paulo's upmarket apartments have opted for electronic metering of hot water consumption for each flat. However, this applies to buildings where water is metered, which is not a common practice in São Paulo. Yet, as discussed in the previous chapter, metering devices for SHW increase the cost of the system making it unaffordable for social housing. A simpler and cheaper solution is used in several projects visited in Thane, where resident associations use a time restriction for the provision of solar hot water: from 6 or 7 am to 9 or 10 am. After 10am, the flow of hot water is shut down (manually or electronically). Given the limited amount of hot water available for the number of flats (see Section 6.5.2), the system often runs out of hot water before 10am, as a large proportion of users take a daily shower or bath in the morning. Moreover, shutting the system at this time of the day ensures that the hot water is replenished for the next morning. In this way, in the words of a SHW distributor working for a manufacturing company, "we allow the system to generate hot water in the daytime" (Interview D5). The system is explained by a male head of family, as follows:

> *Water comes in the morning, until 9 o'clock. Only until 9 o'clock we have solar water. After that, we have normal water. It starts at 7 am… If you want to take a bath using the [solar] tap, then you have to wake up between 7 and 9 am (Interview U10).*

The quote above illustrates a form of self-regulating (hot) water access, influencing the times associated with showering practices.[16] Such forms of regulation also touch upon the perceived legitimacy of different uses of hot water. A young male who does not have SHW at home, when asked if he would use hot water for washing clothes, kitchen utensils or other purposes, comments on how, in his view, hot water use has historically been associated only with showering:

> *In India, there is no such thing as hot water for washing utensils. If you are talking about hot water, it is only for bathing. It is an afterthought! …you will find it in the bathroom only. In the kitchen is very rarely …you don't wash clothes in hot water. We never use hot water for that. It is for special cases only. For example, if I have a very good shirt, and it has been very dirty, so to get that stain out I use hot water ...Otherwise we use normal [cold] tap water (Interview U1).*

[16] For an in-depth discussion of showering practices in the UK see Hand et al. (2005) and Shove (2004).

This quote suggests that the uses of hot water are limited. Yet, for users of SHW interviewed in Thane, the perception of hot water as a 'free' resource has opened possibilities for using hot water beyond bathing and showering. SHW systems are partaking in a transformation of how water is used at home. This is resulting in turn in a discussion around what is seen as a legitimate use of hot water and an emerging attempt to govern water usage by suppressing particular conducts. In a project visit to a bungalow fitted with SHW, the house owner proudly explains the multiple uses of his SHW system: "I am using it for washing utensils, I am using [it] for soaking clothes… because the clothes are very dirty; just dip them in the solar water with washing powder" (Interview U12; Figure 7.8).

Figure 7.8: User testing the temperature of the SHW in order to soak clothes for washing purposes, Thane.

Not all users think this way. A resident of a tower with SHW expresses with concern his reservations about the use of solar hot water for purposes other than showering: "If you use [SHW] for this, then it won't be sufficient. Lots of water would be used for washing clothes, washing dishes, etcetera" (Interview U13). His words are echoed by several distributors of SHW systems in the city, who complain that "some people do not take care of the hot water" (Interview D3). Drawing on the capacities and material qualities of SHW systems, where water heats up slowly over the course of the day to be available for the next, they indicate that there is no such thing as 'free hot water' and prescribe the use of solar hot water for bathing and showering purposes:

> *They misuse it. For example, they use it for clothes, cleaning the floor, or washing utensils. It should be limited for bathing purposes… The problem is that people think that solar hot water is a 'free' thing. But it is not. People don't respect it. They say 'it is free, so why can't we use it for washing clothes, utensils, etcetera'. But the user has to know that the water heats only during a specific period, and that affects the other users or the functioning of the system (Interview D3).*

> *We never allow people to use it in the night because if they are using it, they will misuse it…. If you want 24 hours hot water, you've to double the capacity. 25 litres per person; that is the norm… when you use water for bathing purpose it is OK. Some people are using it for washing clothes; some people are using it for washing utensils; some people are misusing the hot water, the tap is open. It is running out of the water. The hot water generation is limited. The capacity is limited (Interview D5).*

These quotes illustrate three points. First, they illustrate the attempt by system designers to create a specific type of subject (with particular practices of use) in the solar energy regime (Dean, 2010; Legg, 2007b). Second, they illustrate emerging discourses around a joint governing of energy and water conducts in the context of changing energy infrastructures. Finally, they point to a debate around what is and what is not a legitimate use of hot water, or, in other words, of the solar energy embedded in water. This is particularly relevant in the context of urban growth, where an increase in urban population also means changing identities and the adoption of urban lifestyles characterised by greater energy consumption. The analysis shows a tension between the different rationalities involved, for example, between the governmental rationalities around climate change, resource constraints and energy demand which inform the emergence of the solar energy regime and the broader rationalities that prioritise urban growth.

SHW and water consumption volumes: the broader sustainability implications of sustainable energy strategies

Opening up possibilities for changing practices of water use is not the only way in which the transformation to solar energy infrastructures has affected water dynamics, thus generating calls for a regulation of water consumption practices. In São Paulo the transition from electric showers to SHW has been associated with an increase in water consumption. Electric showers require a limited flow of water in order to work properly, reducing consumption to the order of 3 litres/minute (Section 5.3.2). Water temperature is often regulated by the user through adjusting water flows over the course of the shower, by reducing the flow in order to increase the temperature and in this way further limiting water consumption during the cold season. This constraint is not present in solar systems, which have the capacity to provide water in greater abundance. In Brazil, SHW is seen as a shower technology that provides greater comfort. In light of this, the director of the Brazilian Council for Sustainable Buildings claims that "if you use SHW without the proper user education you can increase water consumption" (Interview P37).

Water consumption in SHW is further exacerbated by the change from a water-heating source at the point of use (the electric shower) to one where the heating source is at a distant location, even if it is only a few dozen meters away. Electric showers heat up water instantly, allowing users immediately to start their shower. In contrast, with SHW the user has to wait until the hot water stored in the tanks (located at roof level) arrives to the bathroom. This involves discarding the cold water stored in the pipes and waiting for between 1 to 5 minutes and beyond.[17] In the words of a building sustainability expert at the University of São Paulo, who is a SHW user himself, since his family started using SHW they use

[17] The use of 'hot water pipe loops' (where water is constantly circulating between the thermal reservoir and the point of use) eliminates the need to wait for hot water to arrive, thus avoiding water wastage. However, anecdotal evidence suggests that this system is sparsely used in Thane and São Paulo given its increased installation costs and higher thermal losses.

more water: "we throw that water outside, which here in São Paulo is the most serious problem because there is a lot of water stress" (Interview C7). According to documents prepared by São Paulo's Department of Water and Electric Energy (state level), "nine of the twenty two watersheds in the State (those serving the most urbanised areas of the State) are in critical condition" (Governo do Estado de São Paulo, 2009: 2). The 2006 United Nations Human Development Report considers annual water availability below 1,000m3 as a condition of 'water scarcity' and below 500m3 as 'absolute scarcity'. Yet the Alto Tietê basin, the main river running through the city of São Paulo, presents a water availability of 200 m3/capita/year (Governo do Estado de São Paulo, 2009).

In Thane and São Paulo's solar energy regime the SHW user is imagined as a water and energy consumer in need of governing. Changes in the domestic water heating technology imply changes in water use, affecting consumption periods (e.g. the time of the day for showering), uses (e.g. showering vs. washing utensils) and volumes (e.g. the amount of water used). The use of SHW is creating multiple instances where water and energy practices are being both transformed and stabilised and their conducts are regulated, in an attempt to govern through freedom (Rose, 1999; Rankin, 2001; Section 3.4.3). Thus, making the solar energy regime requires constant work around making the solar user via awareness, education, and the regulation of water and energy conducts. The regime operates as an assemblage in that it is not a final and complete product thanks to the deployment of laws or programmes, but one that requires constant work at a variety of scales, including domestic scales. Just as important, by affecting water consumption practices, the use of SHW (and thus the solar energy regime) has an impact on the sustainability of the city. Nevertheless, a resource-based approach is not the only way to think about the impact of SHW systems in the overall sustainability of the city. Beyond a narrow concern exclusively focused on resource efficiency and availability in the context of energy agendas, SHW systems also play a role in configuring the social dynamics of the city, and through this in expanding definitions of urban sustainability from broader social perspectives.

7.5 SHW, inclusion and exclusion: mobilising solar technologies in the context of social agendas

A final way of considering subject formation in the solar energy regime is related to the way in which such activity relates to issues of inclusion, exclusion and resource distribution. Querying this process of subjectification beyond the identification of environmental identities or the identities defined by the subject's position within the infrastructure network (such as those of producer or consumer) leads to important questions. It requires asking whether all subjects in the solar energy regime are considered equal, or whether the regime is designed to function for certain subjects and not for others, a position informed by the ethos of governmentality. It also requires asking whether the regime fosters urban integration or fragmentation (Graham and Marvin, 2001; McFarlane and Rutherford, 2008). This leads to the possibility of turning around the original question to ask whether what matters is not only how the subject is imagined within the energy regime, but also how energy within the regime is imagined in relation to the subject: what are the social purposes that this new form of energy is endowed with? How does a form of sustainable energy – such as solar – contribute to shaping and changing the subject's position in society? Who is granted access to this form of energy? Such a line of inquiry is critical in Thane and São Paulo, where 35% and 32% of the population live in slums respectively (Thane Municipal Corporation, 2006; Cities Alliance, 2009).

Answering these questions highlights fundamental differences between the dominant forms of contemporary urbanisation in Brazilian and Indian cities, and in doing so, reveals the contrasting urban politics at play in the emerging local governance of energy. Chapter 5 introduced two opposing ways in which governmental rationalities problematising energy in the city were at play: in Thane, solar technologies were revealed as a strategic input for the city's growth agenda; in São Paulo, they appeared as part of a hybrid governmentality addressing an expansion in energy markets alongside social agendas such as the provision of housing.

This section expands on these logics, using the imagined user as an entry point for the analysis. It elaborates on how Thane's urban growth agenda is centred on providing housing opportunities for India's growing middle classes, and how it is only from within this space that renewable energy technologies such as SHW systems figure as a possibility for urban infrastructures. In contrast, São Paulo's experience shows practical ways in which solar technologies can be mobilised towards the delivery of social agendas, playing a role in achieving social equity and poverty alleviation. An important reason for the consolidation of SHW systems within São Paulo's social housing sector lies in their expected contribution towards improving the quality of life of the final users. Through SHW systems, the CDHU managed to enter the sustainable construction debate with a perspective that places a significant emphasis on issues of inclusion and social justice. Drawing on discourses of 'housing with dignity' first articulated by social housing movements (Tatagiba et al., 2012), the CDHU displaced energy efficiency and environmental issues – key governmental rationalities – from the heart of the debate around solar infrastructures, to be replaced by notions of energy affordability and quality of life. SHW systems in social housing lower the expenditure of low-income population on utility bills, thus freeing limited financial resources for covering other needs. In the CDHU's reconfiguration of the solar subject in the context of social agendas, sustainability and energy interventions, above all, are aimed at improving the overall quality of life of the beneficiary population. In both Thane and São Paulo, the SHW user is imagined and conjured into being through design and governance, with particular rationalities informing the construction of this solar subject.

7.5.1 'Housing with dignity': reframing energy and sustainability discourses

Since the turn of the century São Paulo has been praised for implementing a pro-poor and pro-inclusion approach, where progressive policies have been effective at providing the urban poor with greater access to educational opportunities, bank credit, transport and recreational opportunities (UN Habitat, 2010). Housing provision has been recognised as playing an important part of these efforts (Cities Alliance, 2009). When devising strategies for incorporating sustainability in social housing, the CDHU's approach goes beyond environmental issues, placing a significant focus on interventions that also provide social benefits. Its approach to sustainability focuses on three dimensions: city retrofit via the incorporation of sustainable urban planning principles in existing neighbourhoods; the development of actions that promote social and economic sustainability for the beneficiary population; and the adoption of sustainability standards for buildings (UNEP, 2010b). The latter is addressed through a variety of means, with a focus on pilot experimentation in sustainable water technologies – shower timers, water saving devices and rainwater harvesting – and energy interventions such as SHW systems.

The history of social housing is largely a history of lowering housing costs and streamlining construction practices. For this reason, the decision to experiment with SHW is not to be taken lightly: the installation of SHW adds costs to a carefully balanced equation between the amenities provided, the cost of each dwelling, and the total amount of dwellings to be built each year. When considering its sustainability approach, the CDHU was particularly concerned about how the adoption of new construction practices could increase the price of housing units. This concern was both practical and political: sustainability interventions could result in higher construction costs, reducing the total amount of houses built per year at the risk of generating tensions between the CDHU and key urban stakeholders such as the city's multiple social movements that advocate in favour of a social housing agenda. As expressed by a sustainability manager at the CDHU, "that equation for the government is really complex" (Interview P25).

However, the social housing debate in the State of São Paulo is far from being limited to the annual number of dwellings built. Since the 1990s the Brazilian census has qualified the question of social housing, recording not only a lack of housing but also housing of substandard quality (e.g. some *favela* dwellers that, despite having access to housing, live under substandard conditions resulting from a variety of shortcomings such as limited access to sanitary facilities). This opens the possibility of approaching the housing problem not only from a housing shortage perspective, but also in terms of housing quality. The 'qualification' of the social housing debate represented a significant shift in the social housing agenda, leading to discussions around the appropriate quality to be provided and, for São Paulo's housing movements, raising issues around 'dignity' within social housing. Through this debate, São Paulo's social housing movements configured themselves as political actors, demanding not only a 'right to the city' (embodied in a dwelling in a central location) but also making additional claims. What is at stake is a set of values subsumed in the notion of 'housing with dignity' (Tatagiba et al., 2012).

The adoption of SHW systems sits at the core of the tension between quantity and quality in housing infrastructure. For the CDHU, bridging that tension was possible through a broad and open public discussion around the meaning of sustainability in social housing, reassembling the meanings and materialities involved in the solar assemblage for a different set of objectives. In this process, SHW systems became one of several sustainability interventions contributing to housing with dignity and a better quality of life: a wide range of amenities and facilities, a house built with quality materials, better air circulation enhancing indoor air quality and illumination strategies reliant on natural light. As expressed by a staff member of the CDHU, "we managed to include in the discourse the acknowledgment that [sustainability] can imply an investment in the house, but it also means dignity, a better set of values that that housing unit is going to bring" (Interview P25). Thus, the sustainability imperative became an integral element of the 'housing with dignity' debate, enabling an energy strategy that inevitably results in higher costs and therefore a lower number of dwellings built.

Yet, 'dignity' represents more than quality housing; it is also an attempt to subvert the humiliation that accompanies a condition of vulnerability (Kowarick, 2009). In the context of a neoliberal state characterised by its embrace of political rationalities that focus exclusively on meeting the basic needs of those identified as poor or 'deprived' (Giavedoni, 2012), it is worth asking to what extent calls for 'dignity' in the housing/sustainability/energy axis operate as a means to overturn a neoliberal rationality whilst advocating for a more universalising understanding of urban infrastructures. This illustrates the extent to which hybrid and sometimes conflicting rationalities, alongside a different ethos, inform the configuration of the solar energy regime and of its approach to subjects. It also portrays the manifold ways in which resistance is involved in the configuration of the regime (Legg, 2007b).

Social housing programmes in São Paulo have responded to this debate by enshrining notions of 'housing with dignity' within the State's Housing Plan 2011-2023. This establishes "the continuous search for the promotion of dignified housing, which ensures the qualities and conditions of habitability to all individuals in an egalitarian manner" as one of the foundational principles of the State's housing policy (Governo do Estado São Paulo, 2011: 235, translated from the Portuguese). Under this logic, 'quality' housing is associated with providing 'dignified' housing – housing through which it is possible to lead a dignified life. However, 'dignity' also represents a front of struggle; a resistance of social housing beneficiaries to be classified as deprived or as subjects 'in need' (see Section 7.2.3).

7.5.2 Mobilising solar technologies in the context of affordability

When incorporating solar energy technologies, the CDHU embraced a holistic notion of sustainability beyond environmental concerns, positively responding to urban debates about inclusion and social justice. The incorporation of building sustainability features into social housing, including SHW systems, complemented the broad sustainability agenda that the State's housing agency was already pursuing through the provision of housing to low-income population. This is emphasised by a staff member of the CDHU, who, when discussing the sustainability role of solar technologies, quickly emphasises that "there is no sustainability without social inclusion. There is no sustainability with people living in *favelas*… our action is crucial for sustainability" (Interview P25). Housing, as a first step towards urban sustainability, is complemented by infrastructural modes that reduce the financial expenditure of beneficiaries. This is achieved via the financial savings associated with the use of SHW systems.

In the case of SHW in social housing, the confluence between the sustainability and 'housing with dignity' debates relies also on the long-term benefits for the final users, achieved via lower electricity bills. Social housing users in Brazil are estimated to spend between 20 to 24% of their energy bill on water heating (UNEP, 2010a), and a large proportion of this can be saved using SHW. In this case a 'lifecycle' logic that reduces housing costs over the life of the building (Lovell, 2005), is applied in the context of low-income users, providing economic benefits that meaningfully contribute to social justice and poverty alleviation. Such economic benefits occur through the delivery of a social agenda that, through the comfort provided by hot water amongst other things, provides dignity. In the words of Marina, an older female SHW user living in social housing in Guarulhos and former resident of a *favela*, "for me, who never had comfort, I love it here!". Marina thinks that the SHW system is 'wonderful' and 'a privilege', because of the economic savings it provides in the context of the comfort of her house. A similar appreciation of the SHW system, and an account of its economic and environmental benefits, is provided by Isabel, who recently moved into a CDHU dwelling in Cubatao, Greater São Paulo.

> *We live 4 people here. We like the SHW system. First of all because of the economy. But also because it helps with environmental issues. We moved here 3 months ago. Our energy bills have been as follows: the 1st month R$19, the 2nd month $R28, and the 3rd month R$38. …before moving into this house, we were paying between R$70 and R$90 because of the electric shower …but since we moved into the new house we have only been using the SHW. If we would use the electric shower, the energy bill would be higher (Interview U22).*

However, for social housing beneficiaries, moving into their new home often means a series of additional financial burdens often beyond their payment ability. The regularisation of housing conditions implies, in many cases for the first time, the need to pay water and electricity bills. By reducing the expenditure on utility services, the SHW system makes available scarce resources that can be used for other financial commitments associated with housing provision, such as the mortgage and the condominium fees (both of them also often first time expenditures for the beneficiaries of social housing), playing a role in managing financial risks for all parties involved. The importance of lowering operational costs for the beneficiaries of social housing, beyond environmental issues, is emphasised by a sustainability manager at the CDHU in the following way:

> *Why the solar hot water? There is an environmental aspect, but it is a system that generates lower costs. Because who is the population that the CDHU serves? We work with …people of low-income. Therefore, you are generating possibilities for maintenance of their house. Because very often people who come from a background of informal housing do not pay electricity, do not pay water …Because they are doing their own [informal] connections …And in the new model they have to start paying condominium fees, so that is a problem (Interview P25).*

Beyond reflecting on the user, the quote above reflects on a subject of government: an imagined user within the context of social housing. Here an infrastructural design, SHW, plays a role in delivering social needs. This does not mean that the reality of users do not, in practice, conform to the quote's description. Rather, it speaks about how users are configured as subjects in particular ways (Dean, 2010, Rankin, 2001), in this case as a subject of welfare, and how such welfare is achieved through multiple small interventions with the transformation of urban infrastructures being one of them. Yet the SHW user is not always imagined in the same way, as illustrated by how differently they are conceived in Thane, where SHW systems are seen as premium products outside the realm of social agendas.

7.5.3 Powering growth, powering lifestyles: SHW and India's new spaces of consumption

In contrast with the different solar programmes of São Paulo, and in line with Thane's Solar Law, SHW systems in Thane are implicitly understood as a technology of the middle and middle-upper classes. Possibilities for linking issues of poverty and renewable technologies appear limited, as the poor are conceived in an interstice between the rural reality of India and the aspirational dreams of the middle and middle-upper classes. Thane as a 'solar city' bypasses issues of infrastructure provision for the poor and fails to connect with large sectors of society by not being able to mobilise renewable energy technologies towards poverty alleviation. Thane's urban growth ethos, and the ways in which it permeates the configuration of the city's solar energy regime, has significant implications for how renewable energy and its purposes are conceived. In this context, solar technologies are seen as premium products and the solar subject is imagined only in the context of elites and middle classes.

Solar technologies as 'premium products'

Chapter 5 pointed to the material and symbolic role of SHW in underpinning the rapid growth dynamics of the city. Such growth dynamics target middle and middle upper Mumbaikars[18] in search of affordable real estate in the proximity of the 'dream city'. Despite Thane's attempts to reduce electricity needs by means of SHW, residential consumption will grow because of the air-conditioning loads associated with urban lifestyles; the new ways of living of the middle and middle-upper class families that are moving into the city, to the very buildings that now are required to use SHW. The municipal officer behind the city's Solar Law acknowledges this tension, pointing to how "hundreds of buildings are coming up ...and these are also coming with air-conditioning ...

[18] Residents of the city of Mumbai.

naturally these are high-end customers, so their air-conditioning load is going to increase” (Interview P11).

In the absence of a robust and consolidated social housing strategy like the one in São Paulo, SHW systems and other solar technologies in Thane (and Mumbai) are not discussed or imagined in the context of the urban poor. They belong to the emerging middle-upper classes that can afford new flats, or to the rural villages situated in remote areas disconnected to the grid (Kumar et al., 2010; Bhattacharya and Jana, 2009). When discussing the links between solar technologies and the poor, the National Project Manager of India’s UNDP Global Solar Hot Water Project points to the different energy access programmes of the MNRE, adding that the focus is on rural areas (Interview P2). In the words of A. Tragler, the Director of Mumbai’s Slum Rehabilitation Society, “solar heating is something that is unheard of in the slums …It is a thing for the better off people; a high-class thing” (Interview C5). After all, as explained by a manufacturer of SHW systems, the poor can’t afford them, they have no roof to put them on, they have no water supply, and neither hot water much less solar hot water is a priority (Interview D14). Tragler expresses a similar opinion, adding that, if needed, hot water would be heated on the stove through kerosene, as electricity is used exclusively for lights and fans:

> *Solar energy is not really on the list …It would be difficult to implement: houses are small, the upper floor often has a separate family so the family living in the ground floor cannot automatically put up panels on top. There are limited outside open spaces [to put the panels]. And the panels would need a structural roof. But often the roofs are a sheet of steel or plastic. The roof is not strong or sturdy, and is based on bamboo support. The sheets might crack so people would be reluctant to work on them …Then they can use kerosene; the same kerosene they use for cooking, and heat the water on the stove ...There is no use of electricity for heating water. Electricity is for light and fans only (Interview C5).*

In a similar way, the local representative of a SHW manufacturer based in Bangalore sees SHW as “a premium product for middle or higher-middle class people. Poor people are not able to afford that thing. They will be using regular fossil fuels to burn and get their hot water needs to be satisfied” (Interview D5). The urban poor are largely absent from Thane’s Solar Cities Programme. The only reference of the Solar Cities Masterplan to the use of solar technologies within the context of the poor is related to the use of solar lanterns, as a lighting alternative for the 14% of population using kerosene lanterns during load shedding periods (ICLEI, 2011: 43). These thoughts are echoed by the dealers and installers of SHW systems in Thane. When talking about low-income clients, the owner of a small shop of solar technologies points to his offering of solar lanterns for rural areas: “Hut is there. For that he needs only light, so we provide them lantern, small light, kit we are providing” (Interview D1). In contrast with this perspective, his urban clients demanding SHW systems are “highly educated, like doctors, engineers, bankers, those who are having the money”. In line with the discussion around the development of energy identities (Section 7.3.2), he points to how they are also committed environmental citizens who “have made their minds [and think] ‘yes, we have to do something for society’” (Interview D1).

Thane’s carefully staged display of solar technologies combines futuristic and environmental imaginaries, portraying a modern and eco-friendly city in control of its destiny, but above all, capable of absorbing more growth (Section 5.4.3). Its new shopping malls and high-rise towers with swimming pools and luxury flats illustrate the new spaces of consumption of the Indian middle classes (Varma, 2007). A tight local planning system, which includes environmental regulations such as the city’s Solar Law, guides these developments. However, it is exclusively within this space, framed by an urban growth ethos and in the context of rapidly changing lifestyles and patterns of consumption, that Thane’s local governance of energy is conceived and makes sense. The role of the emerging renewable forms of energy is to secure growth. In this context, the solar energy regime appears to operate primarily in the demographically limited space of the elites that Chatterjee (2004) associates with India's civil society (Section 7.2.3), negating the spaces created by the larger 'political society' and the needs of the large majority of the population, living in marginal conditions and representing underprivileged population groups (Chatterjee, 2004).

Opportunities and challenges for SHW in social housing in Thane

Despite this limited recognition of solar technologies in the context of the poor, Thane's Solar Law applies to all new residential buildings. As a result, any social housing built with state support should include SHW. Thane is participating in the national housing programme Rajiv Awas Yojana, which aims at promoting a slum-free India, and the city's Municipal Commissioner plans to provide a space for SHW systems in the delivery of this strategy: "This city is one of the selected few cities for making it slum free city. In that context, we are constructing low-cost housing… And there also we're implementing this SHW system" (Interview P10).

However, two site visits to social housing developments built or managed by the city's Basic Services for the Urban Poor – BSUP unit (which later became in Thane the Rajv Awas Yojna scheme) provided a glimpse of the future challenges for the implementation of SHW in social housing in India. During the first visit, an 8 story residential tower providing temporary accommodation for low-income families displaced by infrastructure works, the SHW system had broken down months before the visit (Figures 7.9 and 7.10). The reasons for this were unclear, and the interviews revealed a multiplicity of elements at play, from lack of maintenance and no user knowledge on how to use the system to persistent interruptions in municipal water and electricity supply affecting the system's performance. In the second visit, to a residential tower in the last stage of construction, SHW systems had not been installed despite users being expected to move in within the coming two weeks. In this case, according to a staff member at the BSPU, a conditional occupation certificate had been issued by the city's Town

Planning Department allowing for the installation of the SHW systems at a later (post-occupation) date. The key concerns of the BSUP are keeping construction costs down and achieving a rapid construction turnaround. To an extent, SHW systems stand in the way of both considerations.

Figure 7.9: SHW systems in social housing, Thane.

Figure 7.10: Malfunctioning SHW systems in social housing, Thane.

The local byelaw making the use of SHW systems mandatory for all new construction (a sovereign mode of power at play; Section 3.3) is a first step for the adoption of SHW in social housing in Thane. However, the challenges ahead lie beyond the realm of regulation and the city's institutional capacities. They lie in the socio-material practicalities of implementing novel modes of infrastructure in the city: the governmental techniques that calculate, standardise and distribute knowledge about solar energy (Section 6.3), the need to forge alignments between the worlds of water and energy (Section 6.4), and the ways by which subject identities are shaped towards the implementation of a new energy regime (Sections 7.3 and 7.4). In practice, these challenges range from skills and abilities for collective maintenance, management and operation, to the broader, fragmented and intermittent connections with and between new and old modes of infrastructure provision (such as water, electricity, SHW and housing). SHW systems are only one minor element in a chain of infrastructure breakdowns affecting the poor (Section 3.2). This includes funding limitations, management shortcomings, and, most importantly, cultural expectations and broader rationalities that prescribe renewable technologies to the spaces of economic growth and market expansion, and limit their possibilities as tools in the service of social agendas (Chapter 5). In the meantime, in the context of solar technologies, the poor are largely unseen, and the only way to imagine them is through the lens of their aspirations and those foisted upon them: the apartments, neighbourhoods and high consumption lifestyles of the middle classes. In Thane, the solar energy regime makes energy visible (Chapter 6) by making visible a particular set of relationships within certain subjects or sectors of the population, whilst obscuring others (Dean, 2010).

7.6 Conclusions

Transforming urban energy infrastructures in Thane and São Paulo is being carried out in ways that go beyond the material transformation of energy systems. Any such transformation needs to involve new forms of subjectivity and consider social relations. The solar energy regime both claims and relies on an ability to influence the subject's identity, and in this way, govern energy conducts. In order to act upon these imagined ways of conceiving the solar subject, local stakeholders enact their right and duty to conduct energy conducts, and claim effectiveness in this process due to their proximity to the user. Through involving local stakeholders in devising and implementing the regime, via a variety of governmental technologies aimed at increasing awareness of energy issues and encouraging the private uptake of renewable technologies, the city aims to put in place its own particular way of locally generating energy. These are the ways by which the local governance of energy creates a new energy citizen.

Over the course of this process, it is not only the user-infrastructure interface that is re-imagined, but also the users themselves. By using SHW systems, and through the resulting growth in energy capacity and reductions in peak electricity demand, the user contributes to the overall management of the grid. Here the user is given a role as a co-manager of urban infrastructures. SHW systems also make users into ambivalent prosumers: autonomous – and thus governmentalised – dwellers that generate their own energy, yet consumers of (hot) water in need of regulation. In Thane and São Paulo, the transformation of urban energy systems has implications for the way the city uses water resources: the change from electric showers to SHW implies a change in practices of water consumption. On one hand, possible new uses for hot water emerge. This is accompanied by a discussion around what are the legitimate uses of hot water, and through this, an attempt to control the use of the new renewable energy forms. On the other hand, by enabling the emergence of a form of consumption that uses greater amounts of water, the reconfiguration of users reveals how the introduction SHW as a sustainable energy technology can in practice upset water balances, thus affecting the overall sustainability of the city.

Examining alternative configurations of SHW, such as the low-cost DIY systems, reveals options for a progressive re-imagination of urban infrastructures. These options are characterised by a redefinition of notions of networked urbanism, where technical and social networks work alongside material infrastructures towards service delivery. Such alternative modes of networked urbanism bring about systems of service provision capable of better responding to local conditions and social and economic needs, particularly in relation to the needs of the poor. They can also support the development of progressive discourses that favour equal and enhanced resource access for all the inhabitants of the city. Finally, they foster identities that are more in tune with the broader rationalities informing the solar energy regime: resource constraints, climate change and the need to act on energy demand.

In an urban world where resource related and climate change interventions are often deemed apolitical or post-political (Swyngedouw, 2010), reviewing the politics of the local governance of energy gains a special relevance. The contrasting cases of Thane and São Paulo reveal a multiplicity of – sometimes overlapping – ethos at play, where growth, market efficiency and accumulation are not the only possible paths, and new discourses around collective objectives and social dignity coexist with an expansion in the free circulation of energy. In São Paulo, with the use of SHW systems in social housing, a local energy regime is reinterpreted within the domain of the social. Here the key aspect that provides legitimacy to the intervention is not the extent to which it results in energy efficiency or savings. Rather, legitimacy comes from the ways by which energy is mobilised in support of broader political objectives, such as those associated with social agendas around universal housing provision. Linking energy, infrastructure and social agendas through an objective around the provision of 'dignity' brings about justice as a recognition of inequality and dignity as a means to address inequality. This stands in sharp contrast to the way in which solar technologies are being rolled out in Thane, where an urban agenda that prioritises growth, in a context of rapidly growing middle classes and under a chain of infrastructure breakdowns affecting the poor, limits possibilities for meaningfully considering solar technologies in the context of social agendas. Thane's form of urbanisation targets the elites and emerging middle classes, precisely because these sectors of the population have the greatest capital available for contributing to the growth efforts.

Engaging with the imagined user has opened a multiplicity of productive avenues of inquiry around the local governance of energy and the implementation of decentralised renewable energy technologies. Overall, a focus on the user has the potential to alter an approach that sees energy-as-a-resource as the primary gravitational point of energy research. This is to be replaced by an approach that focuses on energy-as-a-means: the services and social processes that it enables, from the creation of comfort at home to its contribution to dignity in the context of strategies that promote urban equity. This mode of research also contributes to critically revealing and unpacking the multiplicity of meanings around notions of 'sustainability' in energy interventions. Drawing on notions of post-networked urbanism (Coutard and Rutherford, 2011; Section 3.2.3), this form of energy social science calls for a critical appraisal of sustainability interventions in the city. It calls for an acknowledgement that not all solar technologies are equal; some are more equal than others.

From a theoretical perspective, the chapter illustrates the limitations of theories of governmentality for social and critical analyses around resource and environmental governance. The user, as examined through a governmentality lens, has been seen only as a subjective identity that can be shaped or influenced, but with little agency of its own. In line with critiques to views of power that emphasise authority, power has been seen more from the perspective of "its *intended* rather than by its *actual* effects" (Allen, 2011: 157, original emphasis). An analytics of governmentality provides useful tools for engaging with the user as it is imagined in the makeup of an energy regime, yet this point of view constraints the possibilities for engaging with the user and his practices as active agents within the contestation and/or reinterpretation of energy systems. Whilst this was not the purpose of this thesis, overcoming this limitation requires a different set of tools for the social analysis of energy identities, signalling to possible future research paths.

Chapter 8

Conclusions

8.1 Introduction

The response of cities to the twin challenges of climate change and energy security is bound to transform their social and political configuration. Detailed examination of the energy transformation underway in Thane and São Paulo offers a way of understanding urban low carbon transitions beyond the simple reformulation of policy frameworks or the development of institutional interventions. The thesis portrays the many complexities associated with the implementation of purposeful transformations. It also highlights the multiple stakeholders and scales at play and the fragility and contingency of the emerging renewable energy regime. The possibility of advancing such transitions lie in a sustained engagement with the materiality of the city through the transformation and integration of infrastructure networks. Whilst this materiality shapes the realm of the possible, success also rests on the development of creative responses to deal with the failures and contradictions that arise in the process. Nevertheless, a profound engagement with the materiality of the city does not signify an absence of either the political or the social. On the contrary, the infrastructures that need to be transformed are socio-political in nature. It is precisely this recognition of such social and political essence, and of the cultural and symbolic dimensions of the material networks of the city (Nye, 1994), that lies at the heart of their purposeful transformation.

By way of conclusion, this chapter reflects on the original research questions introduced in Chapter 1 through a discussion around the practical and applied implications of the research. From a scholarly perspective, the chapter distils key contributions and provides a broad discussion of the strengths, limitations and research implications of the thesis. In doing this, it points to the multiple links between energy infrastructures, low carbon interventions and a multiplicity of urban agendas such as growth, social justice, market expansion and resource management. It elaborates on the broader significance and potential of seeing urban infrastructures primarily as a social endeavour; not only one that needs to be governed but also one through which governing occurs. Infrastructure, thus, is the result of specific forms of problematisation; governing with and through infrastructures requires the consideration of both subjectivities and identities and of the social conditions of the subjects interacting with it. The chapter ends with an outline of possible future research paths and questions emerging from the thesis.

8.2 Applied and practical implications of the research

From the outset, this research sets out to answer four largely practical questions. First, how is the on-going urban energy transformation changing the manner in which energy, particularly electricity, is governed? Second, how and with what consequences is this process occurring in cities in middle-income nations? Third, what are the spatial and socio-political implications of this transformation? Finally, what is the specificity of the materiality of solar technologies in this process? These questions are reviewed in this section, with the answers provided via a summary of the applied and practical implications of the thesis. In doing this, the section draws on the empirical material that emerged from Thane and São Paulo and draws connections between the different chapters.

Large and mid-size cities in middle-income nations and rapidly growing economies, such as Brazil and India, are full of opportunities and contradictions. Rapid growth patterns are contributing to an improvement in the quality of life of their citizens, providing better access to housing, transport, education and other services. Yet, this improved access comes with changes in lifestyles that require greater energy consumption and most often result in greater GHG emissions. A tension between local development needs, broader development modes and climate change frameworks at various scales demanding a low carbon future is at play (Bulkeley et al., 2009). The solar energy regime is, in fact, a collection of attempts to bridge this tension and in some cases, such as through São Paulo's DIY SHW, advance different development modes (see Escobar, 2012).

Policy makers drawing on this work will recognise the extent to which the material and social dimensions of energy are co-constitutive of each other. Governing energy infrastructures, and transforming them in response to climate change and security concerns, requires thinking about energy not as a technical challenge but primarily as a social process. This means an understanding of the role of locality, space and scale, alongside an acknowledgement of the social nature of the techniques involved in governing energy processes. It also means a consideration of how the user – as subjectivities and identities – play a role in the configuration of energy systems, and how any attempt to modify such system implies a change in the way users engage with energy infrastructures. Finally, it means an acknowledgement of the way in which energy serves the advancement of specific urban priorities, and through this, a recognition of both the ethos of energy and its political dimensions. Whilst the applied and practical implications of the thesis are manifold, they have been grouped here into four subheadings: the contribution of local domains in advancing the transformation of energy systems (section 8.3.1), the social nature of the techniques required for an energy transformation (section 8.3.2), energy subjectivities and the way energy infrastructures shape identities (section 8.3.3), and the politics and ethos of energy (section 8.3.4). Together, these insights lead to the need to revisit and critically evaluate the presumed sustainability of local and decentralised energies. They also point to the extent to which climate change and energy initiatives have urban implications beyond and above environmental aspects. Finally, they highlight the need to re-imagine energy subjects and reconsider the very purpose of energy in the transformation of energy regimes.

8.2.1 The contribution of local domains to advancing the transformation of energy systems

The local governance of energy is founded upon the adoption of broad rationalities that straddle global, national and local levels, yet are decisively reinterpreted through a local lens. This implies a shift in traditional understandings of energy security, moving from national to local domains and from an emphasis on issues of supply to issues of demand. Chapters 6 and 7 detailed how operationalising such local governance of energy involves transforming a) the specific mechanisms, or governmental techniques, by which energy is governed and b) the subjectivities involved in energy consumption. Energy in the city is not governed exclusively in formal state spaces, but rather by, and through, a variety of stakeholders located within and outside government.

The experience of promoting and implementing solar hot water systems in São Paulo and Thane demonstrates that energy planning and management is not necessarily an exclusive concern of the central state. Local domains, both in the form of city authorities as well as through the networks developed by local stakeholders, can provide a significant contribution to the overall development of a more robust and less carbon-intensive energy system. This points to how responding to climate change implies a spatial transformation around how resources are imagined and governed. The experience of local authorities with solar hot water reveals the need to revise the geographical scale at which energy should be governed (see Bridge et al., 2013). In contrast to the historically centralised electricity regime characteristic of Brazil and India throughout the

20th century (Chapter 2), Chapter 5 illustrated a different way of problematising energy: one where energy is conceived as an urban problem. This problematisation in São Paulo and Thane, framed primarily through governmental rationalities around resource constraints, climate change and energy demand, leads to a portfolio of locally based solutions. Local domains are seen as key entry points for the reconfiguration of the energy regime. Within this space, decentralised technologies such as SHW are configured as the preferred solution. Their implementation occurs through interventions in key urban processes, such as housing provision or planning legislation, and through a reliance on local networks (e.g. social, activist, professional, labour and industrial – see Chapter 6). The extensive use of SHW in response to the local problematisation of energy marks the establishment of a solar energy regime, and with it, the emergence of a local governance of energy.

The type of power required for the low carbon transition is largely governmental power, for it involves shaping the will of disperse stakeholders and a variety of material agents. This power does not lie in the hands of the central state, but rather is shared by a multiplicity of stakeholders within the state and outside of it, and is located at different scales such as the international, the national and the local. It is distributed amongst a variety of agents, both human and material. The in depth evaluation of the tensions and fractures experienced by state actors in São Paulo and Thane in advancing a transformation of the city's energy systems shows the extent to which, when it comes down to transforming the city in response to climate change, the sovereign power of the state is limited. In Thane, for example, the application of sovereign modes of power through mandatory byelaws requiring urban developers to install SHW systems in all new construction run into systematic resistance, despite a widespread recognition by builders and urban developers of the environmental value of the strategy. Whilst urban developers would comply with the law, their use of undersized or low quality systems limited the achievement of the objective. In São Paulo governmental forms of power, where the freedom of those in need of governing is enlisted, yielded greater results. This is exemplified by the city's reliance on standards to secure quality, aided by the voluntary involvement of industry players in their development. Whilst the state plays an important role in directing, promoting, guiding and encouraging a transition in energy systems, the agencies involved are diverse and multiple. The powers involved in the transformation of energy systems are geographically dispersed across the city; the agencies are scattered. The empirical narrative included in chapters 4 to 7 demonstrates how non-governmental organisations, large and small business, voluntary organisations and individuals are endowed with a form of power that advances, blocks, transforms and contests the proposed energy transition. It also illustrates the primary role played by certain objects and non-human agents, whether they are pipes, collectors, showers, baselines or masterplans. Not all these objects are technological in the traditional sense of the word, and many of them are embodied with a form of politics that expresses itself in the form of priorities and orientations, as demonstrated by the operations of standards, targets and other calculative devices.

Thinking about energy locally brings forward a new set of priorities and opportunities. Involving local domains in large scale energy planning encourages a new set of (material, social and economic) circulations. For example, in Guarulhos, in the outskirts of São Paulo, the proposed solar energy regime is aimed partly at capturing the monetary flows associated with the provision of energy services for the local economy. These circulations are more likely to respond to local problems and concerns whilst drawing upon local opportunities for the provision of solutions. With SHW, locally based circulations provide opportunities for efficiencies via resource integration, such as water and energy (in the form of heat, and aimed at the replacement of electricity). Here the seemingly mundane worlds of domestic piping are revealed as key contributors to a different energy future. Urban nature, as a form of circulation, is also transformed by the adoption of solar energy. Scaling SHW use as a form of urban infrastructure opens possibilities for reimagining this city-nature interface. SHW is an energy technology that is highly in tune with local ecologies, as it relies on local weather patterns and needs to consider local variability and seasonality, such as Mumbai's monsoon and the cold but dry and sunny winter of São Paulo. As examined in Chapter 5, SHW infrastructures, rather than overpowering nature, require an alignment with local natural cycles and their uncertainties.

8.2.2 The social nature of the techniques required for an energy transformation

Framing energy problems primarily as technical problems is common within the world of low carbon transitions. Drawing on such misconception, those working on GHG reduction often assume that the solution lies in the adoption of new technologies. The experience of Thane and São Paulo demonstrates the extent to which the adoption of new technologies is as social as it is technical. The specific techniques used for advancing a low carbon transition are in fact techniques of a social nature. Two types of techniques were evaluated in this thesis: techniques of calculation and techniques of standardisation. Techniques of calculation, primarily used in Thane, are used to quantify energy locally and in this way make it visible. Energy baselines, masterplans, and targets not only calculated energy and drew attention to its existence, but also constructed it as an object in need of local governing, setting out specific strategies for intervention. The Thane Solar City Masterplan includes, for the second time in the history of the city, a comprehensive energy baseline identifying qualities and quantities of the energy consumed locally (ICLEI, 2011). It sets out to transform such forms of consumption, signposting possible paths and identifying the risks likely to derail the process. It embraces a set of numerical targets, and in doing this, through the combination of calculative techniques for measuring and forecasting past and future consumption, it develops a common language capable of establishing dialogues with a variety of other agencies with similar interests working at different scales. In this way, the 10% reduction target embraced by Thane acts as a device that connects local and national governments, and serves as a benchmark for local performance in the context of a national energy crisis. Yet, for as much as local energy was calculated, the Masterplan fell short of actual material interventions, thus limiting its agency. Calculation techniques on their own fail to account for the material dimensions of the solar energy regime, limiting its effectiveness. Their reach sits within discursive domains, and as a result, they lack the purchase characteristic of standards, which are more effective at governing socio-material relations.

In São Paulo, the emphasis has not been so much on the use of calculative devices but on forms of standardisation. Standards here operate as normalising procedures, enabling the conduct of conducts of the various human and material agencies involved. By shaping the way relationships take place, standards play a key role in facilitating the governing of a dispersed form of energy generation. Like some of the calculative devices used in Thane, standards in São Paulo also played a role in linking local and national domains. At times they were developed at the national level, through a partnership between the Brazilian Association of Manufacturers of Solar Hot Water Systems (DASOL) and the national institute for standardisation INMETRO. At times, they were produced locally, by a variety of business associations operating in tandem. These standards, regardless of their local or national origin, were embraced by local procedures including São Paulo's Solar Law and the terms of reference guiding the procurement process of the CDHU. But in contrast to the calculative techniques of Thane, standards in São Paulo operate more clearly in a relational manner. Through standards such as the PROCEL Seal for energy efficiency, the INMETRO quality testing procedures for SHW equipment, the Brazilian Supplier Qualification Programme for Solar Heating Systems (QUALISOL) and the *Specification Guide for São Paulo's Solar Law* (ABRAVA, 2008), three types of relationship were standardised: material relationships, knowledge circulations and an alignment of water and energy systems. In shaping relationships, standards intervened at social, material and resource interfaces. They set out guidelines clearly stating the working procedures, responsibilities and expectations of manufacturers, governments and users; the different material qualities involved in making solar energy (such as the materials required in the manufacture of solar collectors); and most importantly, the points of connection between the circulations of energy and those of water, a key dimension in the makeup of solar energy. Overall, standards were devised as a system that would let different worlds speak to each other, articulate efforts and generate new (joint) work. Whilst Thane's calculation was somehow inward looking and largely focused on energy, standards placed a greater emphasis on relationships beyond the exclusive world of energy.

It is perhaps the emphasis that standards place on governing the very nature of relationships that reveals the extent to which these are not simply neutral technical devices. On the contrary, standards are also political devices, capable of creating boundaries, establishing priorities and defining orientations. The standards developed by INMETRO, which guide the quality of materials of the SHW systems that are used in both social housing and in the context of São Paulo's Solar Law, define a boundary around the type of SHW systems that are considered legitimate and appropriate. They sort incumbent and newcomers, and in doing this, limit possibilities to engage with emerging alternative technologies that may have a greater social component. This is the case with the DIY SHW system promoted by the non-profit *Sociedade do Sol*, which operates through a network of volunteers embracing ideas around universal energy access and promotes the right to solar energy knowledge. The form of infrastructure network promoted by the *Sociedade do Sol* re-imagines users. Beyond being seen as resource consumers, users are reconstituted as an integral part of the infrastructure system with responsibilities around manufacture and maintenance. This in-depth user engagement with infrastructure, in addition to providing energy in the form of hot water, seeks to generate a reflection around the social implications and environmental impacts of resource use. In the face of the current environmental challenges, standards need to be flexible to allow for engagement with newcomers and outsiders, as these alternative socio-material systems can be a productive source of transformation. They are often one that puts in place a system of provision that is more capable of responding to local conditions and socio-economic needs, fostering a set of identities that are more in tune with the transformation required to achieve low carbon living.

8.2.3 Energy subjectivities and the way energy infrastructures shape identities

The low carbon transition requires the development of new subjectivities and identities. Chapter 7 highlighted the role that imagined subjectivities play in the makeup of the solar energy regime. In the case of Thane and São Paulo, this involves creating a new type of energy subject, aware of environmental and energy challenges whilst also willing to act as a responsible citizen who acknowledges a duty of care towards both nation and the environment. Given the nature of SHW systems, where the user owns energy generating infrastructure, resource consumers can be seen also as producers. The extent to which this happens in varied. At one end of the spectrum are those who purchase an industrially manufactured SHW system, and therefore rely on external knowledge and expertise for manufacture, installation and maintenance. These subjects play a relatively passive role for, whilst still energy producers, they are nevertheless bound to be consumers of energy infrastructure through its purchase in the marketplace. At the opposite end of the spectrum, SHW opens up the possibility for more clearly defined modes of 'prosumption' within urban infrastructures: new user-infrastructure configurations where the user is also the manufacturer and gets involved in the installation and maintenance of the system. This is so in the case of São Paulo's DIY SHW systems, where users are encouraged to buy the required materials and assemble the SHW unit themselves. In both cases, beyond just being autonomous citizens (governmentalised) capable of generating their own energy, users play an active role in the co-management of the grid by reducing peak demand loads and increasing the overall availability of electricity capacity. In this way, the SHW prosumer contributes to overcoming two key problems of Brazil and India's energy system, as illustrated in detail in chapter 5. As suggested by Ritzer et al. (2012), the greater the integration between the object and subject of prosumption, the greater the possibilities for identities that are shaped by this relationship. This active involvement and the formation of identities around the generation of low carbon energy are likely to result in greater energy awareness, an important element of any energy conservation initiative.

Energy identities are not shaped solely by active participation in the configuration of urban infrastructures. In a clear display of governmental rationalities, where governmental power operates through freedom by aligning the objectives of the governed with those of the governor, Thane and São Paulo use a range of techniques to involve the subject in energy projects with the objective of influencing the way subjects source and use energy. This is particularly relevant in the development of Thane's Solar City programme, where a Solar City Cell (still in planning as of 2011) is expected to play an important role in convincing energy users to switch to SHW by providing one to one information and support. In tandem, a Solar City Stakeholder Committee, composed of representatives of local organisations involved in energy issues, plays an important role in guiding the overall development of the programme. Together, the Solar City Cell and the Solar City Stakeholder Committee enable public participation in energy decisions and develop public awareness on the topic. The public response to Nagpur's equivalent of the Solar City Cell, the city's Renewable Energy and Energy Efficiency Resource Centre, is characterised by statements of appreciation and support. However, these references also place an important value to the use of renewable energy for the good of the nation, illustrating one way in which notions of citizenship get embroiled with energy identities, and where rights, duties and national identities collude towards the creation of more favourable environments for energy conservation.

Finally, a consideration of energy subjects and subjectivities leads to an inquiry around the multiple ways in which the energy behaviour of subjects is governed. Changing attitudes towards energy is not as straightforward as the use of visitor centres such as the Solar City Cell would lead to believe. Other – more subtle and perhaps more effective – mechanisms emerge outside of institutional spaces, such as in the everyday workings of the providers and users of SHW. In Thane, the adoption of solar energy has led to the emergence of new modes for regulating its use through a reflection around what is considered a legitimate use of hot water. Whilst solar energy is seen as an unlimited resource, in practice solar hot water is a limited resource given the maximum daily capacities of the systems installed. In the context of collective SHW systems, where the resource is shared by an entire building, governing energy involves regulating the use of hot water: its times, amounts and purposes. In light of the limited capacity of SHW systems and their inability to supply hot water to all the residents of a building, users and dealers of SHW have started to ask questions and take positions concerning the legitimate and appropriate use of hot water. Bathing only? Bathing and laundry? Or bathing, laundry and dish washing? This is an active debate in the domestic spaces where solar hot water operates as a limited but shared resource. This is creating new imaginaries and discourses around both energy and water. Some of these, in an attempt to reduce consumption, state that solar hot water should be used for bathing purposes only. In a related way, new practices that enable governing this resource are emerging, such as limiting the provision of solar hot water to certain times of the day, usually in the early morning to align provision with bathing schedules. What is important here is how, in the solar energy regime, the regulation of energy is achieved through the regulation of other resource, specifically water. This also points to the inseparability of resource flows in the city, where changes in one resource could have positive or negative impacts on another resource. In São Paulo it is common knowledge that where SHW replaces electric showers greater comfort is achieved, as users are no longer bound by the limited water flows of the electric shower. Yet, anecdotal evidence suggests that the use of SHW, whilst reducing electricity use, can affect the city's water balances by promoting greater water consumption. Without considering an integrated approach that looks in a holistic way at how users engage with both energy and water, there is a risk of increasing sustainability around one resource whilst negatively affecting another. The transformation of energy infrastructures is a cross cutting topic with the capacity to affect, in positive or negative ways, different urban processes. Therefore, a crosscutting set of linkages should be examined and, when appropriate, potentiated. The consolidation of a local energy regime provides opportunities for re-thinking what energy is for, and for collectively discussing use priorities and the legitimacy of particular energy uses.

8.2.4 The politics and ethos of energy

Perhaps the most important consideration when examining the role and place of the subject within the emerging local energy regimes is the recognition of its political dimension. In this light, the subject of solar energy initiatives is not only a consumer/producer of energy (an urban dweller who interacts with infrastructure in a variety of ways), but also a citizen with specific political and economic interests and priorities, and who is positively or negatively affected by the transformation of energy systems. As examined in Chapter 3, urban infrastructures are inherently political, as they open or close possibilities for accessing the key resources required for urban living (McFarlane and Rutherford, 2008; Graham and Marvin, 2001). Reviewing the politics of low carbon interventions means recognising that these are not apolitical or post-political processes (Swyngedouw, 2010), as by their very nature they are likely to affect how specific sectors of society access key resources. Where the transformation of urban energy systems occurs, whether it is in the spaces of Thane's middle classes or in the low-income neighbourhoods of São Paulo, matters politically. In cities such as Thane and São Paulo, the low carbon transformation of energy systems has the potential to increase or decrease conditions of social exclusion, and it is paramount to ensure that new modes of urban infrastructure do not become enmeshed in old systems of exclusion and domination.

Comparison between São Paulo and Thane showed how relatively similar interventions promoting solar hot water can be anchored in very different ethoses. These ethoses ranged from urban growth and market expansion to social and environmental agendas. These, understood as moral forms embedding principles and orientations, play a key role in shaping the outcome of the intervention. As illustrated in Chapters 5 and 7, the different ways in which the solar energy regime is being configured in Thane and São Paulo reveals two contrasting modes of urbanism. These are characterised by different ways of conceiving the role of resources: in one case, energy operates as input for urban growth, whilst in the other as the means for living lives of dignity. These different ethoses around the local understanding of energy have implications for who is granted access to the new (solar) forms of energy that are being developed. The case of São Paulo revealed a hybrid ethos that combines market expansion with a pro-poor agenda, through private electricity utility companies and the regional social housing agency acting together. The result is the reinterpretation of the local energy regime within the domain of the social, yet still in the context of the market. Energy here plays a role as a tool for redistribution and social justice. Such arrangement has created a space where energy is seen clearly as a means to enable services and social processes rather than a resource that needs to be managed. The association of SHW systems with pre-existing discourses around dignity, particularly those enacted by São Paulo's social housing movement (Tatagiba et al., 2012), gives energy a prominent place in a debate that sees justice as a recognition of inequality and dignity as a means to address it.

In a strikingly contrasting manner, Thane's experience revealed an urban growth ethos where SHW plays a key role in negotiating the ecological tensions associated with rapid growth and an increase in resource consumption in the midst of resource constraints. Here energy serves the needs of growth, and those who benefit from such growth are the ones likely to benefit from the new low carbon energy forms that are being developed. In the case of Thane, the primary beneficiaries are the elites and middle classes that make-up for the city's rapid growth, through high-rise residential developments that, despite increasing the overall energy requirements of the city, come fitted with a low carbon source for a segment of their energy requirement. The recognition of the ethos of energy points to how the legitimacy of low carbon interventions comes from multiple fronts, not always directly from the primary intended objective. This highlights the need to evaluate in a critical manner the presumed sustainability of local and decentralised energies. Given their renewable nature, decentralised and small-scale energy technologies such as SHW are often deemed 'sustainable' without a full consideration of their impact on social or environmental systems (Coutard and Rutherford, 2011). Whilst a local energy intervention might achieve increased sustainability from a purely energy perspective, this intervention is arguably of limited value if it reinforces or increases social exclusion or urban inequality. For low carbon and sustainability transformation of local infrastructures to be successful, they need to be deeply ingrained within local realities and agendas beyond exclusive environmental concerns.

Given the primary role that energy plays in development (United Nations, 2012), the ethos of the energy regime has implications for the overall development model that is being advanced. In cities of the South, recognising local energy dynamics and the role of renewable technologies beyond the spaces of the elites and growing middle classes entails opening the renewable energy strategy to broader social agendas around inclusion. In the case of India, this means considering an energy subject that is not limited to the minority 'civil society' identified by Chatterjee (2004), but that operate in the space of what he has called the 'political society'. The energy and development debate is often considered largely from a rural perspective, given the high rates of electricity access in urban areas (over 93% in India and over 98% in Brazil). However, the different ways in which solar energy is being advanced in Thane and São Paulo, one with an emphasis on urban growth and the other with an emphasis on affordability and a contribution to the quality of life of those in greatest need, suggest that the energy and development debate is also an urban debate. Such debate goes beyond issues of access, recognising the need to consider issues of affordability, reliability and informality (United Nations, 2012). Most importantly, this opens a debate around the contribution of energy to wealth redistribution, the achievement of social justice and the advancement of different development models. São Paulo's experience with the use of SHW in social housing reminds us of the importance of asking questions around the social value and political orientation of the new energy modes that are emerging in response to the need to reduce GHG emissions. It also teaches us that the use renewable energy towards dignity and social justice far outweighs its direct environmental benefits. What is at stake here, in the contrast established by Thane's emphasis on urban growth and São Paulo's emphasis on social housing, is the advancement of different development models through contemporary low carbon responses.

8.3 RESEARCH CONTRIBUTIONS

The thesis makes three empirical contributions. First, it uncovers the local distinctiveness of local energy regimes by identifying how seemingly similar urban processes across the globe have very different local manifestations. In pointing to the specific local manifestations of this energy transformation, the thesis shows how such incorporation of diversity and multiplicity is precisely what enables the local energy regime to operate. Second, it reveals how the local energy regime is underpinned by an urban ethos of energy. Third, it draws out the re-territorialisation of energy processes occurring through the establishment of a solar energy regime. In addition, the thesis makes one methodological contribution by drawing simultaneously from approaches on comparative urbanism and ethnography, and reflecting on the tensions and opportunities provided by this methodological approach.

8.3.1 The local distinctiveness of local energy regimes

At first sight, the transformation of urban energy infrastructures that is occurring in large and small cities across the globe appears to be occurring through similar processes. Rationalities with a global purchase such as climate change, resource constraints and energy demand play a common framing role. However, in-depth research in Thane and São Paulo shows the extent to which these seemingly similar processes have very different local manifestations. The transformation of urban energy infrastructures is therefore a process that is underpinned by a global episteme, but where common ways of thinking about the energy problem are adapted and reinterpreted at local levels in significantly different ways. Both cities engage with climate change debates at national and international levels; they both consider issues of resource constraints, alongside the need to think differently about energy demand. Yet, in interpreting these rationalities, both cities draw on a different ethos, mobilise a different set of governmental techniques, and approach the subject in markedly different ways.

It is precisely through this process of differentiation, in adapting and reinterpreting the broad rationalities that constitute the regime (climate change, resource constraints and energy demand), that the local scale becomes authorised to govern energy locally. The resulting solar energy regime in São Paulo is based on processes of standardisation, where the relationships between different agents are tightly governed. It also embodies social logics that extend across energy processes and provides the benefits of solar technologies to a broad variety of urban dwellers, both rich and poor. In contrast, Thane's solar energy regime is primarily based on processes of calculation, with a strong emphasis on making energy visible, and through this, constituting energy as an object of local government. It is informed by a local rationality around urban growth that directs the emphasis to specific sectors of the population, particularly the elites and the middle classes.

Making energy locally requires diversity and multiplicity. Embracing local distinctiveness within energy processes involves the adoption of diversity and multiplicity at multiple levels, a characteristic that enables the local governance of energy to operate. This diversity is evident in the multiple scales that are involved in configuring the regime, from the global to the national, the local and the dwelling; in the variety of the agents involved in making the regime and in their dispersed nature, across scales but also geographically within the city; in the modes of power involved, where sovereign techniques that rely on coercion work in tandem with governmental techniques that rely on freedom; and finally, in the variety of techniques involved in the make-up of the regime, such as calculative techniques (effective at making energy visible) and standardisation techniques (effective at governing relations). Implementing a local energy regime is not about one-dimensional or targeted strategies. It is a multi-sited and often fragmented and contingent process filled with diversity and, emanating from this, contradiction, breakdown and resistance. Managing conflict and dissent, as well as learning from failure, are key steps in the process of experimentation with new energy forms at the local level.

8.3.2 An urban ethos of energy

A key aspect in establishing local differentiation is the embracing of a particular ethos that reflects local concerns. Or at least, the concerns of those who occupy governing positions within the regime. From this perspective, it is precisely the ethos that confers an urban dimension to the emerging regime. In shaping the solar energy regime, Thane's urban growth ethos and São Paulo's social ethos (exercised through social housing provision), serve the function of reinterpreting energy from a local perspective. This dictates where solar energy processes occur, with which populations, and for what purposes. In doing this, the ethos is revealed as playing a constitutive role in the solar energy regime. This ethos is particularly important, as it opens possibilities for mobilising energy either as a mechanism for the preservation of the status quo, or as a progressive and transformative force for society.

8.3.3 The re-territorialisation of energy processes

Section 3.6 refers to the re-territorialisation of energy as a process of re-codifying meanings, redefining subjects and boundaries, and re-establishing circulations. The analysis of the solar energy regime in Thane and São Paulo shows how such re-territorialisation works in practice. The re-codification of meaning occurs through the ethos of the solar energy regime, which embraces local concerns and agendas (as discussed in the previous section). Subjects are redefined by reconfiguring consumers into prosumers, and by reformulating energy identities drawing on notions of environmental awareness and citizenship. Governing energy occurs in alternative (non-centralised) sites, thus redefining boundaries in various ways. First, between the scales involved in energy generation and management. Stakeholders operating on a national scale see the need to consider the local as an appropriate site for intervention, and the dwelling is reconfigured as a site for generation and management. Second, between infrastructure and user, through an explicit incorporation of the user as a constitutive element of the infrastructure. Finally, boundaries between the sites of generation and the city are also redefined, as the city now contains an element of local generation.

The re-territorialisation of energy also occurs by creating new forms of circulation, particularly the circulation of energy through water. As examined earlier in this chapter (Section 8.2.1) SHW relies on a specific arrangement of materialities for the creation of a mechanism that absorbs energy from the sun and circulates it to the final user in the form of hot water, in this way creating a set of efficiencies and optimisations. Yet, this circulation is not exclusively material; energy is also generated through the circulation of knowledge around plumbing. These circulations respond to specific urban dimensions, as the form and density of the city (e.g. high-density neighbourhoods with residential towers or low-density neighbourhoods with single story homes) determine their potential and limits. Energy is generated in the proximity of the sites of consumption and through local relationships: roof terraces, municipal offices where policies are discussed, NGOs where strategies are devised and promoted, building professionals and professionals within the SHW industry, business associations, local distributors of white goods, and renewable energy visitor centres. SHW favours local autonomy (micro-local energy independence) alongside local forms of non-material connectivity (e.g. professional networks around building techniques, or the voluntary knowledge networks of the NGOs promoting solar energy). In line with a definition of territory as the rendering of space as a political category (Elden, 2007), the reterritorialisation of energy in the city reflects how constituting a local energy regime is political.

As discussed above in Section 8.2, Chapter 5 shows how the local problematisation of energy is not exclusively an urban process. Multiple other scales are involved. These, from the transnational to the national, play a role in defining and framing local energy, via, for example, national energy initiatives or transnational efforts for GHG reduction. Governing energy in the city requires putting in place the means for establishing scalar dialogues with other agencies outside local domains, as illustrated in Chapter 6 with targets as a mechanism that aligns the objectives of central and local governments. Governmental rationalities play an important role in linking scales within the local governance of energy. For example, as illustrated in Chapter 5, discussions around climate change integrate various priorities and work-programmes across scales and open opportunities to mobilise additional national and international financial resources towards local agendas. The national and the transnational are not the only scales involved in the local governance of energy. Micro scales also play a key role, illustrated in Chapter 6 by, for example, the neighbourhood and its densities and the dwelling typology and its internal configuration of water flows via plumbing. Overall, the solar energy regime re-works the scales involved in energy processes, drawing attention to their nature as an effect rather than a structuring element (Legg, 2009: 234). In this context, it is worth querying the extent of the boundaries of the local governance of energy. The change towards the city as an entry point for energy intervention, and the resulting local governance of energy, does not mean that such domain is bounded by the political or administrative boundaries of the city. It operates more as a borderless space; one where the limits of local, national and global domains are transgressed, uncertain and in constant change (Barry, 2006).

The spatial reconfiguration of the geographies of energy through solar technologies also implies a temporal reconfiguration. Doreen Massey, when highlighting that time and space are born together, speaks of time as "the medium within which change occurs … [the] change-through-inter-relationality is one of the mechanisms in the creation of temporality" (2004: 274). The use of solar technologies in the local governance of energy, and the reconfiguration of space occurring through that, makes us think about the temporalities of the city and how these relate to energy: from annual climatic cycles to daily peak electricity loads. Intervening in energy through solar technologies requires engaging with these temporalities, by acknowledging and working with them. This is exemplified by the need for SHW systems to account for periods of inaction over cloudy months, demanding alternative arrangements for hot water. The temporalities of this mode of energy infrastructure also become evident in the case of electric showers and peak electricity demand. Here local showering practices generate time patterns of energy consumption that affect the overall functioning of the electricity system, with SHW opening possibilities to solve this.

8.3.4 Drawing simultaneously from approaches on comparative urbanism and ethnography

A fourth contribution made by the thesis relates to its methodological approach. One of the key challenges for urban research, as it moves into a renewed comparative period (McFarlane and Robinson, 2012; Nijman, 2007), is the identification of methodological approaches capable of accounting for the emerging cosmopolitan paradigm within the field (Robinson, 2006; Section 4.2). An important question here is how to achieve depth and a holistic understanding of the urban in multi-sited spaces of research. This question is of greater relevance after the traditional barriers and categories that structured the research efforts within the realms of the known and familiar – by narrowly determining what can and cannot be compared (e.g. developed vs. developing, rich vs. poor) – have been dismantled.

This thesis sets out to achieve such depth and holistic understanding through embracing an ethnographic sensibility. The combination of methods and sensibilities used, referred to as a 'traveling ethnography of urban technologies', pushed the boundaries of both ethnography and comparative urbanism. Ethnography facilitated a full immersion that provided a research experience rich in data. However, the demands of travel constrained the ethnographic approach and created anxieties around what Marcus (1995) calls the 'attenuation of the power of the fieldwork'. It has to be acknowledged that the result is not an ethnography, or at least not in the traditional sense. Yet, the methodology used offered a productive combination of data sources, sites and moments. Further exploration of the interface between ethnography and comparative studies is required to achieve a better balance between the comparative approach and ethnography. This contribution is not intended to be a final statement or be based on a consolidated approach; rather, the contribution lies in opening the problem to questioning and highlighting the challenge.

8.4 Evaluation of the conceptual framework

The thesis used an analytics of governmentality to unpack the emergence and workings of a local governance of energy. The work drew primarily on categories developed by Dean (2010), Legg (2007b) and Li (2007a; 2007b) (Table 3.2). The resulting conceptual framework (Figure 3.1) was productive for bringing to the surface the material and non-material mechanisms that compose the solar energy regime, the dispersed viewpoints from which it emerges, and the forms by which governmental rationalities are enacted on the ground. The different dimensions of governmentality examined – episteme, ethos, telos, techne, visibility, forging alignments, managing failures, and identity formation – were useful entry points for discussing issues around materiality and territoriality within the regime, and through this, to understanding its political nature. An analytics of governmentality proved useful to examine the emerging energy regime in a critical manner, and to develop and inquiry about how a specific urban process is influenced and affected by agendas and interests located at a variety of scales. Finally, conceiving the solar energy regime as an assemblage, pointed to its dispersed nature and fragility, contingency and lack of completion.

However, in using the framework I found two limitations: possible conceptual overlap and a limited ability to engage with the agency of the subject. Despite efforts to achieve conceptual clarity, the framework poses the risk of conceptual overlap. Categories located at different levels of analysis, such as governmental rationalities and episteme, and governmental techniques and techne, at times appear to operate in the same way. Rather than hiding from this, I attempted to use this ambiguity in productive ways. Finally, the use of the framework limited possibilities to engage with the agency of the final users of SHW systems (see Section 7.6). The framework guided the research towards a focus on the governors, regardless of their position as state or non-state actors. However, I acknowledge the importance of considering the agency of final users in the makeup of the solar energy regime. This is a possibility that is further explored in Section 8.7, when discussing future lines of research emerging from the thesis.

One remaining question in the evaluation of the interplay between conceptual framework and empirical analysis is the extent to which the changes and reconfigurations of infrastructure witnessed on the ground speak of regime transformation or are limited to changes in subsectors within the regime. This is an important theoretical point of inquiry, as it raises questions around regime scope, extension and the location and constitution of boundaries. From an empirical perspective, the transformation that Thane and São Paulo are undergoing equates to a significant change in the way energy is imagined, sourced and managed. This thesis argues that this transformation speaks of regime change, despite the fact that the actual contribution of SHW systems to the local energy mix, albeit unmeasured, is likely to make up only a small proportion of the overall demand. At a conceptual level, a regime – defined as "the relatively organised and systematised ways of doing things" (Dean, 2010: 268) – proves to be a broad category that operates like a set of Russian dolls: regimes of practices include within them regimes of government that in turn incorporate a multiplicity of other regimes. For the notion of regime to be useful, it needs to be accompanied by a clear definition of its boundaries, and a debate around their constitution. Without this, the use of the notion of regime could end up muddling the waters rather than adding clarity. In both São Paulo and Thane, it is not only the electricity regime what is changing, but also a regime around how the city engages with the interface between population, resources and infrastructures.

8.5 Implications for how energy research is conducted

Over the past decade, energy has become a more prominent topic within the social sciences. In sociology, Guy & Shove propose 'a sociology of energy', as a pragmatic approach that examines "the construction of the energy 'problem'" and engages with theories of social change to explain "the social dynamics of energy consumption and… the social organisation of energy-conserving measures and practices" (2000: 2). In anthropology, Strauss et al. see a possibility to 'reenergise' the discipline through energy studies, to be achieved through a more in depth consideration of "how we harness …energy to construct socially meaningful worlds" (2013b: 10). In science and technology studies, a research agenda around 'energy social science' has been proposed as a mechanism to understand stability, transformation, vision and scenarios around much needed long term changes in energy regimes (Rohracher, 2008: 158). Finally, in human geography, the use of spatial categories (such as location, landscape, territoriality and spatial differentiation) is proposed for a better understanding of "what living in a low-carbon economy will be like" (Bridge et al., 2013: 331). These are but a few voices within the social sciences that are mobilising the discipline towards a more in-depth understanding of energy processes.

This thesis has been inspired by the broad efforts described above. In doing so, it puts forward a way of doing 'energy social science' which retains a strong engagement with the spatial and material dimensions of energy, and productively combines discursive, governance and technological domains. It advocates for an understanding of the local character of energy processes, drawing attention to the specificity of locality in energy interventions. Yet, by looking at more than one locality, it enables a form of learning through comparison (McFarlane, 2011), which in the case of this work has become a form of South-South learning. It also argues for the relevance of retaining an understanding of how social and material worlds are entangled in the making of energy. Finally, it provides a specific way of engaging with the user, not strictly through an examination of how energy is used (e.g. through an analysis of the practices of energy consumption; see Shove et al., 2012), but through how the user is imagined, highlighting how constructing subjectivities also shapes energy systems. The result is a form of doing energy research where energy comes to life as a new academic subject, grounded in the realm of the social sciences and outside the domain of the engineer. Energy studies appear, thus, not as a technical discipline but as a key form of input for the understanding of the political economy of resource flows.

This way of doing energy research, and the emerging 'energy social science', has been precipitated by a form of crisis: the challenges posed by climate change and resource constraints. As scholars of urban infrastructure studies are well aware, un-black boxing the operation of infrastructure networks is both a form of upsetting the established order and opening opportunities for positive change (Graham and Marvin, 2001; Graham and Thrift, 2007). As ANT scholars suggest, innovations, trials and moments of breakdown offer sites of transparency and opportunities for understanding the intricate and often invisible nature of the relations at play (Latour 2005). Transitions and innovation in the context of climate change are new processess of translation, where a new set of agents (including the growing set of organisations that focus on this topic, a new set of technologies proposed as solutions and even climate change itself) are re-imagining, reconfiguring and re-translating energy, waste, transport and other urban networks. Such networks, up to very recently 'black-boxed' and simplified, are gaining new meanings and following a new set of agendas and programmes. During this transitional period, the programmes of all actors (incumbent and new technologies, advocacy organisations, government bodies, energy companies, business, users and regulations, amongst others) are going to be "borrowed, bent, displaced, rebuilt, reshaped, stolen, profited from, and/or misrepresented to generate the effects of agency, organisation and power" (Law, 1992: 387). Here the city as a laboratory for experimentation offers opportunities to reveal hidden meanings and dynamics (Hodson and Marvin, 2009a; Bulkeley and Castán-Broto, 2013). The newly found instability of infrastructure networks, their unsuitability and change, allows for their un-black boxing. Climate change brings about this instability by instigating a transition, rendering existing infrastructures obsolete and signalling the need for change. In this way climate change and the transition to new urban infrastructure models presents a challenge to the dominant (black boxed) networks of the city, both the physical infrastructure networks as well as the wider socio-technical assemblages that mediate access to energy, water, waste, telecommunications and transport. In this transition scenario, what was taken for granted cannot be taken for granted anymore. Systems, regulations, machines, behaviours, and overall the relations of the network need to be reconfigured to achieve low carbon scenarios. The transition requires infrastructures to be un-black boxed and re-deployed, networks to be re-enacted and governing rationalities, technologies and subjectivities to be re-created. And as the resulting network aims to regain simplification, new forms of social and material resistance are likely to appear. As cities respond to climate change, a new order settles into place, revealing issues of power and domination and enabling new players as well as new forms of governing to emerge. In this scenario, energy research needs to place particular attention to existing and changing social and political configurations at a variety of scales. The politics of energy cease to be conceived primarily within the realm of the geopolitical, as it becomes transparent how energy processes construct and are constructed by the domestic, the local and the everyday.

Researching energy in the manner stated above is not just a matter of adjusting the approach through the adoption of specific conceptual positions. This is also achieved through the use of specific methodological viewpoints, particularly the use of ethnographic approaches for the study of energy infrastructures. Taking the ethnography of infrastructure seriously, and applying it to energy systems, means recognising that these systems are deeply embedded in social arrangements. It also means analysing their extensive reach or scope beyond single events or objectives, examining how they construct communities of practice and use, and uncovering the politics of the standards that regulate them (Leigh-Star, 1999; Leigh-Star, 2002; Leigh-Star and Bowker, 2006). Beyond the valuable contributions of Leigh-Star, an ethnography of infrastructure allows examining hands on and in detail how energy systems play an essential and pervasive role in governing the present.

The emerging 'energy social science' is, thus, a discipline that transcends the domains of urban infrastructure studies and positions itself around the constitution of power relations and the state in contemporary society. As pointed by recent ethnographic studies around politics and infrastructure, infrastructure reveals forms of political rationality as well as different forms of constituting the political (Larkin, 2013). As such, it needs to be understood as "integral to the conduct of politics" (Barry, 2013: 2). In this context, it is worth revisiting the work of the 'intellectuals of plumbing' and their recognition of drains and sewerage, the material basis of the 19th and 20th century sanitized city, as essential assets for the establishment of apparatuses of security within a liberal order (Osborne, 1996; see also Kaika, 2005; Kaika and Swyngedouw, 2000). Infrastructure systems, such as the energy forms examined in this thesis, create and sustain dynamic political and moral spaces whilst simultaneously emerging "as closed territorial entit[ies] and as open, networked form[s]" (Harvey, 2012: 76). Is the emerging low-carbon energy of the 21st century a new urban technology through which specific political rationalities are being consolidated? A detailed and continued analysis of infrastructure as a form of constituting both power and the state stands at the base of the future research agendas that emerge from this thesis.

8.6 Future research

Thinking about energy infrastructures as a way of constituting the state and forming moral and political spaces would require, in addition to engaging with the emerging ethnographies of infrastructure, insights from an ethnography of the state (such as Hibou, 2004; Ferguson and Gupta, 2002; and Navaro-Yashin, 2002). Within this space, and drawing directly on the results of the thesis, several relevant research questions emerge. For example, are renewable technologies such as SHW more or less conducive to democratic and participatory political arrangements? How are these low carbon energy interventions responding to the social justice needs characteristic of the city of the South? Are centralised energy regimes, where the central state plays a greater role in structuring an energy strategy, stable and consolidated formations? Or, on the contrary, are they just as fragile and contingent as the local energy regimes examined in this thesis? And finally, how does the agency of the final user affect the formation of the local energy regime? How does the interface between the values and practices that make up such energy user contribute to or stand in the way of the sought-after transformation? Four possible future avenues of inquiry have been identified in order to answer these questions. These call for an examination of the specific politics and democratic potential of renewable energy technologies; of the way in which issues of social justice are considered in the configuration of energy networks; of the agency of the user in shaping renewable energy regimes; and of the similarities and differences – within regime consolidation – in the makeup of centralised and decentralised energy regimes. These four research agendas are briefly discussed in this final section.

In a seminal study on the politics of energy, Timothy Mitchell (2009) compares the politics and democratic potential of oil and coal. As I developed this research, Dean's work would often come to my mind and make me wonder about the democratic potential of solar technologies. The first avenue for future development that I would like to explore is informed by Mitchell's line of inquiry, and builds on the material examined in Chapter 7. How does solar energy play a role in shaping, transforming or preserving the subject's position in society? Are solar technologies an instrument for democratisation? How can new technologies, such as solar and renewable energies, create new forms of exclusion or inclusion (Barry, 2001: 18)? This line of research is of particular relevance for a contemporary understanding of the global South, as countries such as India deploy large scale programmes for the development of solar generation capacity (Section 2.4.2) and as 'raising powers' – such as China, India and Brazil – invest in low carbon energy technologies in other developing economies such as African nations (Power, Bulkeley, et al., 2013). It echoes recent scholarly questions around justice in relation to energy systems and their transformation (Walker, 2008; Buzar, 2007; Hall et al., 2013; Bickerstaff et al., 2013). Yet, it places a greater emphasis on the scalar nature of these dynamics, particularly though establishing a dialogue with the city.

As exemplified by the case studies examined in the thesis, the low carbon transition can also be an opportunity to advance progressive approaches through the recognition of issues of urban equity and social justice and the mobilisation of climate interventions towards solving pre-existing challenges and structural inequalities (Luque et al., 2013). In the city of the global South, characterised by overlapping environmental and social priorities, advancing a low carbon agenda with a limited understanding of its socio-political implications can result in greater inequality, the intensification of forms of exclusion and regressive approaches towards both resources and the environment. At the heart of this future research agenda lays an understanding of the low-carbon transition as both social and political, since only an explicit recognition of this can open the required debates around different collective futures and a new set of priorities.

Advancing this research agenda requires revisiting classic debates around urban politics and social justice (Harvey, 1996; Harvey, 2009; Rawls, 1999), yet through a direct interpretation in the context of energy access. Here social justice would be considered in light of contemporary work around the transformation of electricity networks. This line of research draws directly on the contrast established between the dominant ethoses of the energy transformation in Thane and São Paulo. It builds on an identification of the multiple possible ethoses of energy, and the extent to which these play a role within social agendas demanding justice and redistribution for the urban poor or within the growth spaces of the elites and middle classes of the global South. Such research agenda has the potential to discuss the uneven geographies associated with electricity access. Drawing on Harvey (2009), the interface between energy and social justice can be considered from three different perspectives. First, as a matter of distribution and thus, equity. Second, in relation to a response to contemporary urban challenges, where social justice is further problematised by engaging not only with issues of distribution, but also with issues of production, efficiency, and the configuration of consumption. Finally by considering the role of social movements and protest in the configuration of the city's 'socio-electric' dimension, where social justice is recognised not as eternal justice and morality, but rather as contingent to social processes and to the multiple viewpoints and reinterpretations that emerge from resistance.

The experience of São Paulo and Thane suggests that the politics of urban energy services articulate an important agenda based on the power of urban dwellers to transform, re-imagine and reshape the electricity network. A third future possible line of research calls for a specific understanding of the agency of the user in shaping renewable energy regimes. Users, through positive engagement, resistance or everyday practices, influence the workings of the local governance of energy. The key here is not to see the user exclusively as an imagined subject, but as an active player in the configuration of energy regimes. This line of research offers opportunities for complementing the analytics of governmentality used in this thesis with a conceptual framework that provides more direct points of contact with the user, such as theory of practice (e.g. Shove et al., 2012; Gram-Hanssen, 2011).

Finally, the analysis of the solar energy regime can be complemented with an analysis which, drawing on the same analytical tools used in this thesis, evaluates the make-up of centralised energy regimes. This would involve an in-depth historical and contemporary understanding of centralised electricity regimes, in order to draw comparative insights and establish dialogues between centralised and decentralised energy logics. In pursuing such line of research, it should not be assumed that centralised energy modes are, in effect, based on single nodes of control. Like decentralised regimes, centralised regimes are likely to operate based on a multiplicity of nodes, in contingent, fragile and dispersed ways, and through multiple points of pressure across the territory. They also relate to broader flows that transcend the nation state and connect to local levels, embedding scalar logics. Yet, the operation of rationalities, ethos, telos, forms of visibility, governmental techniques and other dimensions of governmentality is likely to be different from those encountered in the analysis of a decentralised and renewable regime. A more nuanced understanding of centralised electricity regimes, paired with the current analysis of decentralised regimes, is likely to contribute to a more in depth picture of contemporary energy systems. Together, these forms of energy analysis can contribute towards regime transformation.

Appendix I

Interview Schedules

TYPE OF ACTOR – USER

INTERVIEW SCHEDULE 1

- Can you tell me how do you use the [urban experiment]? What do you use it for? Do you find it positive or negative, and why?

- Who else is involved in its use? How do they use it?

- How did you first learn how to use it? Can you tell me your experience of this?

- Where you involved during the period when the installation was being discussed or planned? How?

- Tell me about your household before and after the installation of the [urban experiment]? What changed and how?

- How has the [urban experiment] changed the way in which you think about energy? About your [household]?

- What happens when the [urban experiment] breaks down? Who do you call? How do they fix it?

- Has it happened in the past? How has this affected you?

- In your view, what have been the positive and negative aspects of the project?

- Do you think that this project could enable users or local authorities to think about energy in a different way? How?

TYPE OF ACTOR - OWNER

INTERVIEW SCHEDULE 2

- Why did you decided to install the [urban experiment]? (e.g. motivations)

- What are its advantages over other sources of energy?

- What type of support did you received in the process?

- Did the [policy] or other government incentives or programmes played a role in the process?

- What difficulties did you experience? (e.g. getting planning approval, deciding on which technology to use, getting the appropriate technical knowledge, others)

- How satisfied are you with the final outcome?

- Can you tell me the story of how did you pay for the [urban experiment]?

- Do you think that this project could enable users or local authorities to think about energy in a different way? How?

TYPE OF ACTOR - PROMOTER[1]

INTERVIEW SCHEDULE 3

- Why did you decided to promote this project? This type of technology?
- How did you go about promoting it?
- What are/were the key aspects of your support?
- How do you think that the project responds to the specific needs of the city? How does it connect with the specific urban agenda of the city?
- How do you see that the project could play a role in changing the way in which the city approaches issues of energy?
- What barriers are yet to be overcome to further promote the use of this technology?
- Do you see opportunities for this project to be replicated in other parts of the city? Where and how?

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[1] Interviewees likely to be:

- Members of promoting organisation
- Government stakeholders (local/regional/national)
- Members of public stakeholder committee involved in the development of policies/programmes

TYPE OF ACTOR - DELIVERY ACTOR[2]

INTERVIEW SCHEDULE 4

- How did you get involved in this project? Can you narrate to me the story of your involvement?

- Over the course of this involvement, who were the people that you interacted with the most? What was this interaction about? How?

- Do you think that solar technologies have a role to play in [Nagpur]? Why? Why this technology in particular?

- How do you think that the technology is likely to impact the way in which energy is planned for? delivered? used?

- What technical limitations are associated to this technology? What technical possibilities?

- How do the technical aspects of the technology incorporate or clash with cultural aspects? With patterns of use?

- What role do you see for the technology in the future?

- In this particular project, what difficulties have you run into so far? What difficulties do you think will appear in the future?

- Do you see opportunities for this project to be replicated in other parts of the city?

[2] Interviewees likely to be:

- Engineers and technicians involved in planning, sourcing and installing the project
- Engineers and technicians involved in repair and maintenance

TYPE OF ACTOR - FUNDER

INTERVIEW SCHEDULE 5

- Can you tell me the story of how did you funded this project (urban experiment)?

- Why did you choose those funding mechanisms in particular?

- What other funding mechanisms are there available?

- Could you give me an overview of the financial arrangements and conditions? (e.g. where does the money come from, what is the payback period)

- How would it be possible to increase the options for funding?

- How do the funding mechanisms limit or potentiate the use of the technology?

- Do you see possibilities for this funding mechanism to be implemented in other parts of the city? Why?

TYPE OF PROJECT – VISION DEVELOPMENT[3]

INTERVIEW SCHEDULE 6

- Would it be possible to say that there is a future vision of [Nagpur] as a ‘solar city’? What would this vision consist of? What are the most important elements that shape this vision?

- Who were the key stakeholders involved in the development of this vision? What role did they played? Do you think other stakeholder could/should have been involved and why?

- How does this vision respond to the current problems or key challenges facing the city?

- What are the key challenges associated to the achievement of this vision? What needs to be done in order to get there?

- What changes need to be done in the way in which the city approaches (plans for, delivers and uses) energy in order to achieve this vision?

- In your opinion, why are solar technologies appropriate for the city? Which solar technologies are the most appropriate and why?

- What do you think is the role of [the urban experiment] in the achievement of this vision?

[3] Interviewees likely to be:
- Members of organisation promoting solar technologies
- Members of local authority
- Members of public stakeholder committee involved in the development of policies/programmes

TYPE OF PROJECT – POLICY INITIATIVE[4]

INTERVIEW SCHEDULE 7

- Can you briefly to me the history of the [solar energy] policy? When was it discussed for the first time? Who were the key stakeholders involved in its development? What were the defining moments in the process of developing it?

- What do you think are the most important achievements associated to this process?

- What are the limitations of the policy?

- Were there any stakeholders against it? Why?

- How has the media and the general public received the policy?

- How is the policy changing/likely to change the way in which energy is approached in the city?

- What do you think has been the impact of the policy so far? What could be its impact in the future?

- Would you say that the policy is appropriate specifically for [Nagpur]? Why?

- How would you say that the policy has influenced the overall development of the [urban experiment]? What would have been of this project without the policy?

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[4] Interviewees likely to be members of:
- Organisation promoting solar technologies
- Local authority
- (Elected?) government officials involved in promoting the policy
- Public stakeholder committee involved in the development of policies/programmes

TYPE OF PROJECT
PLANNING MECHANISM (CITY LEVEL)[5]

INTERVIEW SCHEDULE 8

- Tell me the specific story of the [planning mechanism]. Why was there a need for it? Who was involved in developing it? What role did the different stakeholders played? How long did it take?

- What were the main difficulties in the process of developing it?

- Can you tell me about the sources of information that you used for developing it? What type of information did you used? Who provided you with that information? How? Why did you use that information?

- Is there any information that you would have liked to used but you did not? Why?

- Who uses it? Can you tell me a story of how it has been used?

- Does it specifically respond to issues and needs in [Nagpur]? How?

- How would you say that it has influenced the overall development of the [urban experiment]? What would have been of this project without it?

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[5] Interviewees likely to be:
- Members of organisation promoting solar technologies
- Members of local authority
- (Elected?) government officials involved in promoting the policy
- Members of public stakeholder committee involved in the development of policies/programmes

TYPE OF PROJECT
PLANNING MECHANISM (PROJECT LEVEL)[6]

INTERVIEW SCHEDULE 9

[*Note: planning application documents or equivalent to be reviewed in advance*]

- Can you tell me the story of the development of the [planning application documents]? Why were they needed? Who was involved in developing them? What are the main aspects covered by these documents?

- Did you encounter any difficulties in the process of developing them?

- Who provided the technical support? How was this support provided?

- How was the interaction with the [city council/municipal corporation] for the purpose of obtaining approval? How long did it take?

- What are the main differences between the [planning approval documents] and the actual project that was installed?

[6] Interviewees likely to be:
- Owners of project
- Engineers and technicians involved in developing the planning application documents

Appendix II

List of Interviews
Participatory Observation
Project Visits

LIST OF INTERVIEWS - INDIA

All interviews were conducted between March and July 2011

(Names have been excluded to preserve confidentiality)

No.	Role	Organization	Type	Location
TECHNOLOGY PROMOTERS				
P1	Director, Solar Cities Program	Ministry of New and Renewable Energy	Government (national)	Delhi
P2	National Project Manager	UNDP / GEF Global Solar Hot Water Project	Transnational	Delhi
P3	Director	ICLEI-SA	Non-profit	Delhi
P4	Director, Solar Cities program	ICLEI-SA	Non-profit	Delhi
P5	Project Officer (1)	ICLEI-SA	Non-profit	Delhi
P6	Project Officer (2)	ICLEI-SA	Non-profit	Delhi
P7	Leader of the Executive Branch	Thane Municipal Corporation	Government (local)	Thane
P8	Executive Engineer, Town Planning	Thane Municipal Corporation	Government (local)	Thane
P9	Municipal Commisioner (former)	Thane Municipal Corporation	Government (local)	Thane
P10	Municipal Commisioner	Thane Municipal Corporation	Government (local)	Thane
P11	Executive Engineer, Energy Department	Thane Municipal Corporation	Government (local)	Thane
P12	Engineer, Energy Department	Thane Municipal Corporation	Government (local)	Thane
P13	Team leader and two project executives (group interview), Basic Services for the Urban Poor Unit	Thane Municipal Corporation	Government (local)	Thane
P14	Asistant Director of Town Planning (former)	Thane Municipal Corporation	Government (local)	Thane
P15	Project Manager	Maharashtra Energy Development Agecy	Government (regional)	Thane
P16	Senior Project Officer	ICLEI-SA	Non-profit	Nagpur
P17	Executive Engineer, Lighting Department	Nagpur Municipal Corporation	Government (local)	Nagpur
P18	Executive Engineer	Nagpur Municipal Corporation	Government (local)	Nagpur
P19	Deputy Mayor	Nagpur Municipal Corporation	Government (local)	Nagpur
P20	Manager, Renewable Energy and Energy Efficiency Resource Center (former)	Nagpur Municipal Corporation	Government (local)	Nagpur
DELIVERY STAKEHOLDERS				
D1	Owner	Arun Akshay Urja Shop	Private (dealer)	Thane
D2	Partner	Lahs Enterprises	Private (dealer)	Thane
D3	Partners (group interview)	Urja Solar	Private (dealer)	Thane
D4	Partner	Uniser Industries	Private (dealer)	Thane
D5	Asstistant Manager,	Raccold Ltd	Private	Thane

	Project Sales		(manufacturer)	
D6	Consultant	Energetic Consulting	Private (consultant)	Thane
D7	Director	Sharada Inventions	Private (manufacturer)	Thane
D8	Senior Manager for PV Systems	Moser Baer Photo Voltaic Ltd	Private (consultant)	Delhi
D9	Partner	Elegant World	Private (dealer)	Nagpur
D10	Owner	SDC Power Technologies Pvt. Ltd	Private (dealer)	Nagpur
D11	Partner	MM Solar Private Limited	Private (dealer)	Nagpur
D12	Senior General Manager, Sales & Marketing	TATA BP Solar India Ltd	Private (manufacturer)	Bangalore
D13	Head of R&D	EMMVEE Solar Systems Pvt Ltd	Private (manufacturer)	Bangalore
D14	Technical Director	EMMVEE Solar Systems Pvt Ltd	Private (manufacturer)	Bangalore
D15	Area Sales Manager	Raccold Ltd	Private (manufacturer)	Bangalore
D16	President	Maharashtra Solar Manufaturers Association	Private (business association)	Delhi (via phone)
INSTITUTIONAL USERS (NON-FINAL USERS)				
I1	Director	Puranik City	Private (real estate)	Thane
I2	Director	Sudarshan Sky Gardens	Private (real estate)	Thane
I3	Two plumbing engineers (group interview)	Hiranadani Group	Private (real estate)	Thane
I4	Site engineer	DOSTI Realty Ltd	Private (real estate)	Thane
I5	Chief Engineer Officer	Satkar Residency	User (commercial)	Thane
I6	Medical Superintendent	Thane Municipal Corporation	User (commercial)	Thane
I7	Operations Manager	Heritage Hotel	User (commercial)	Nagpur
USERS (FINAL USERS)				
U1	Resident	Raj Roshan building	User (residential)	Thane
U2	Residents (group interview)	Laxmi Narayan Residency	User (residential)	Thane
U3	Resident	Rutu Estate	User (residential)	Thane
U4	Supervisor	Shubharambh Estate	User (residential)	Thane
U5	Resident	Thyme Tower, Everest World	User (residential)	Thane
U6	Resident	Acacia Tower, Hiranandani Estate	User (residential)	Thane
U7	Residents Association Secretary and Residents Association Chairman (group interview)	Fairytale Estate	User (residential)	Thane
U8	Residents (group interview)	Burlington Tower, Hiranandani Estate	User (residential)	Thane
U9	Residents (group interview)	Shubharambh Estate	User (residential)	Thane
U10	Resident	Avior Building, Kabra Galaxy	User (residential)	Thane
U11	Resident	Mayflower, Hiranandani Meadows	User (residential)	Thane
U12	Resident	Pushpanjali Residency	User (residential)	Thane
U13	Resident	Kores Nakshatra Estate	User (residential)	Thane
U14	Supervisor	Crown Building, Hiranandani Estate	User (residential)	Thane
U15	Residents Association Treasurer and Residents	Blue-bird Co-op Housing Society	User (residential)	Thane

	Association Chairman (group interview)			
U16	Residents Association Secretary	Crown Building, Hiranandani Estate	User (residential)	Thane
CONTEXT INTERVIEWS				
C1	Project Manager	Auroville Energy Products	Private (consultancy)	Delhi (via phone)
C2	Project Manager	Emerging Ventures Ltd.	Private (consultancy)	Delhi
C3	Consultant	Indian Institute of Human Settlements	Academia	Delhi
C4	Professor	IIT-Bombay	Academia	Mumbai
C5	Director	Slum Rehabilitation Society	Non-profit	Mumbai

LIST OF INTERVIEWS - BRAZIL

All interviews were conducted between August and November 2011

(Names have been excluded to preserve confidentiality)

	Role	Organization	Type	Location
TECHNOLOGY PROMOTERS				
P21	Program Director, Secretaria Verde y de Medio Ambiente (former)	Municipality of São Paulo	Government (local)	São Paulo
P22	Councillor	Municipality of São Paulo	Government (local)	São Paulo
P23	Director, Depto de Iluminacao Publica	Municipality of Guarulhos	Government (local)	Guarulhos
P24	Project Manager, Department for Product Development	CDHU	Government (regional)	São Paulo
P25	Sustainability Manager	CDHU	Government (regional)	São Paulo
P26	Energy Efficiency Manager, Assessor da Presidencia	CDHU	Government (regional)	São Paulo
P27	Engineer, Hydraulic Instalations Department	CDHU	Government (regional)	São Paulo
P28	Manager of Urbanism Projects	CDHU	Government (regional)	São Paulo
P29	Water Metering Program	CDHU	Government (regional)	São Paulo
P30	Building Works Manager, Sao Paulo Metropolitan Region	CDHU	Government (regional)	São Paulo
P31	Program Director, Solar Cities	Vitae Civilis	Non-profit	São Paulo
P32	Director	Sociedad do Sol	Non-profit	São Paulo
P33	Monitores (2) and school director (group interview)	Sociedad do Sol and Santa Maria School	Non-profit / educational establishment	São Paulo
P34	Manager	GIZ	International	São Paulo (via Skype)
P35	Monitor	Sociedad do Sol	Non-profit	São Paulo
P36	Monitor	Sociedad do Sol	Non-profit	São Paulo
P37	Director	Conselho Brasileiro de Construção Sustentável	Non-profit	São Paulo
DELIVERY STAKEHOLDERS				
D17	Director, Electric Showers Group	ABINEE – Brazilian Association of Electric and Electronics Industry	Private (business association)	São Paulo
D18	Communications Director	DASOL – Brazilian Solar Hot Water Manufacturers Association	Private (business association)	São Paulo
D19	Director	ABRASIP – Brazilian Association of Engineers of Bulding Systems	Private (business association)	São Paulo
D20	President	ABRAINSTAL – Brazilian Association of Installers of Bulding Systems	Private (business association)	São Paulo

D21	Director	Cia Brasileira de Energia Solar	Private (dealer)	São Paulo
D22	Director	Exxa Global	Private (dealer)	São Paulo
D23	Engineer	Gomes Engenharia	Private (consultant)	São Paulo
D24	Sales representative	Soletrol	Private (manufacturer)	São Paulo
D25	Director	Solar evolution	Private (dealer)	São Paulo
D26	Engineer	Aquecedores Cumulos	Private (dealer)	São Paulo
D27	Business Director and Consultant (group interview)	Soletrol	Private (manufacturer)	São Paulo
D28	Engineer	Agência Energia Projeto e Consultoria em Energia Solar	Private (consultant)	São Paulo
D29	Director	Energias Eficiencia Energetica	Private (consultant)	São Paulo
D30	Engineer	Engineering Hill International	Private (consultancy)	São Paulo
D31	Architect and Energy Consultant	Freelancer	Private (consultancy)	São Paulo
INSTITUTIONAL USERS (NON-FINAL USERS)				
I8	Director of Community Programs, Director of Environmental Management, Commercial Director, Marketing Director (group interview)	AES Eletropaulo	Private (utility)	São Paulo
I9	Energy Efficiency Manager	EDP Bandeirantes	Private (utility)	São Paulo
I10	Community manager	Elektro	Private (utility)	Franco da Rocha
I11	Environment representative	Sinduscon-SP (Sao Paulo's construction industry union)	Private (real estate)	São Paulo
I12	Auditor	CDHU	Government (regional)	São Paulo
I13	Manager, Rubens Lara Project	CDHU	Government (regional)	Cubatao
USERS (FINAL USERS)				
U17	Resident	---	User (residential)	São Paulo
U18	Resident	---	User (residential)	São Paulo
U19	Resident	---	User (residential)	São Paulo
U20	Resident	---	User (residential) [of electric showers; not SHW]	São Paulo
U21	Resident (1)	Rubens Lara Estate (low income housing)	User (residential)	Cubatao
U22	Resident (2)	Rubens Lara Estate (low income housing)	User (residential)	Cubatao
U23	Resident (3)	Rubens Lara Estate (low income housing)	User (residential)	Cubatao
U24	Resident (1)	Belem L (low income housing)	User (residential)	São Paulo
U25	Resident (2)	Belem L (low income housing)	User (residential)	São Paulo
U26	Resident (1)	Brasilia (low income housing)	User (residential)	Guarulhos

U27	Resident (2)	Brasilia (low income housing)	User (residential)	Guarulhos
U28	Resident (3)	Brasilia (low income housing)	User (residential)	Guarulhos
U29	Resident (1)	Vila Florida (low income housing)	User (residential)	Guarulhos
U30	Resident (2)	Vila Florida (low income housing)	User (residential)	Guarulhos
CONTEXT INTERVIEWS				
C6	Excecutive Secretary, Climate Change and Economics Committee	Municipality of São Paulo	Government (local)	São Paulo
C7	Professor	Departamento de Engenharia de Construção Civil (PCC), Escola Politécnica, Universidade de São Paulo	Academia	São Paulo
C8	Professor	Universidade Federal de Santa Catarina	Academia	São Paulo (via Skype)
C9	Architect	Freelancer	Private (consultancy)	São Paulo
C10	Architect	Amado & Marcondes Arquitetos Associados	Private (consultancy)	São Paulo
C11	Social worker	CDHU	Government (regional)	Cubatao

INSTANCES OF PARTICIPATORY OBSERVATION (INDIA AND BRAZIL)

	Instance	Lead organization	Type	Location	Lenght
	INDIA				
1	Work at ICLEI-SA offices	ICLEI	Promotion of solar technologies	Delhi	~4 weeks
2	PV + Solar India Expo 2011	--	Trade industry exhibition	Mumbai	2 days
3	Evolving Thane	Maharashtra Chamber of Housing Industry	Real estate exhibition	Mumbai	1 day
4	Installation of solar hot water system (*)	Sudarshan Sky Gardens (building)	Technology implementation	Thane	2 days
5	Installation of solar hot water system	Dosti Vihar (building), Lahs Enterprises	Technology implementation	Thane	½ day
6	Site visit with prospective clients of SHW systems (*)	Lahs Enerprises	Technology implementation	Thane	1 day
7	Site visits with with prospective clients of SHW systems	Arun Akshay Urja Shop	Technology implementation	Thane	2 days
8	2nd Stakeholders Meeting, Solar Cities Program	Thane Municipal Corporation	Government meeting	Thane	½ day
9	Nagpur's Renewable Energy and Energy Efficiency Centre	Nagpur Municipal Corporation	Technology promotion	Nagpur	3 days
	BRAZIL				
10	Work at Vitae Civilis offices	Vitae Civilis	Promotion of solar technologies	São Paulo	~12 weeks
11	Training workshop on 'Low Cost Solar Hot Water Systems'	Sociedad do Sol	Technology development	São Paulo	1 day
12	Adult learners class on 'Low Cost Solar Hot Water Systems'	Sociedad do Sol & Santa Maria School	Technology promotion	São Paulo	2 hours
13	Installation of 'Low Cost Solar Hot Water Systems' in residential housing	Santa Maria School	Technology implementation	São Paulo	½ day
14	Workshop on fiscal incentives for solar technologies	Vitae Civilis	Promotion of solar technologies	São Paulo	½ day
15	Brazilian Congress of Solar Hot Water (CB-Sol)	DASOL (Brazilian Solar Hot Water Manufacturers Association)	Promotion of solar technologies	Campinas	2 days
16	Inauguration of a CDHU solar hot water project in the City of Tiradentes (low income housing)	AES Electropaulo	Promotion of solar technologies	São Paulo	1 day

Projects marker with a (*) are also included also in the Project Visits table

PROJECT VISITS
(INDIA AND BRAZIL)

	Instance	Lead organization	Type	Location
	INDIA			
1	Roof mounted PV system	Thane Municipal Corporation	PV solar project in government building	Thane
2	Solar Air Conditioning at Chatrapati Shivaji Maharaj Hospital	Thane Municipal Corporation	Concentrated solar (solar parabolas) project in government building	Thane
3	SHW system (roof mounted), Raj Roshan building	Private visit	Residential SHW system	Thane
4	SHW system (roof mounted), Acacia Tower, Hiranandani Estate	Private visit	Residential SHW system	Thane
5	SHW system (roof mounted), Shubharambh Phase 4	Private visit	Residential SHW system	Thane
6	SHW system (roof mounted), Thane Kores Nakshatra Estate	Private visit	Residential SHW system	Thane
7	SHW system (roof mounted), Blue bird Co-op society	Private visit	Residential SHW system	Thane
8	SHW system (roof mounted), Hiranandani Crown Building	Private visit	Residential SHW system	Thane
9	SHW system (roof mounted) in single story house (1)	Private visit	Residential SHW system	Thane
10	SHW system (roof mounted) in single story house (2)	Private visit	Residential SHW system	Thane
	SHW system (roof mounted), Sudarshan Sky Gardens building	Sudarshan Sky Gardens	Residential SHW system	Thane
11	SHW system (roof mounted), Sai Baba Vihar Complex SHW	Lahs Enterprises	Residential SHW system	Thane
12	SHW system (roof mounted), Vihar Valley	Lahs Enterprises	Residential SHW system	Thane
13	SHW system (roof mounted), Hiranandani Meadows, Gemini Tower	Hiranandani Group	Residential SHW system	Thane
14	SHW system (roof mounted), Sasket Transit Buildings	Thane Municipal Corporation	Residential system (low income housing)	Thane
15	MMRDA site social housing project	Thane Municipal Corporation	Low income housing (no solar tehnology installed)	Thane
16	Solar Cell	Thane Municipal Corporation	Public information centre	Thane

17	SHW system (roof mounted), Satkar Residency	Satkar Residency (hotel)	Commercial SHW system	Thane
18	EMMVEE Factory	EMMVEE	SHW manufacturing site	Bangalore
19	Solar traffic lights	Thane Municipal Corporation	Solar PVs for traffic lights	Thane
20	Solar traffic lights	Nagpur Municipal Corporation	Solar PVs for traffic lights	Nagpur
21	Solar PV's for government offices	Nagpur Municipal Corporation	PV solar project in government building	Nagpur
	BRAZIL			
22	Low cost solar hot water systems at the Favela Pretoria	Elektro	DIY SHW system in informal housing	Franco de Rocha
23	Rubens Lara (low income housing)	CDHU	SHW in low income housing	Cubatao
24	Belem L (low income housing)	CDHU	SHW in low income housing	São Paulo
25	Environmental Education Centre	Municipality of Guraulhos	DIY SHW system for public display and public information centre	Guarulhos
26	Vila Florida (low income housing)	Municipality of Guraulhos	SHW in low income housing	Guarulhos
27	Brasilia (low income housing)	Municipality of Guraulhos	SHW in low income housing	Guarulhos

Appendix III

List of codes used

PRIMARY CODING

1st level	2nd level
Automation	n/a
Awareness & education	n/a
Breakdown & maintenance	n/a
Business structure	n/a
Centralised - decentralised	n/a
Challenge	Health and safety; institutional; integration of systems; knowledge; market structure; political; quality; social issues; technical
Climate change	n/a
Conflict	n/a
Consumption	n/a
Deregulation	n/a
Development path	n/a
Energy and resources	Access and governing; efficiencies and transfers; holistic approaches; load shedding and blackouts; national level/peak demand; practice of consumption; practice of production; resource integration; tariffs; water interface
Energy and resources	n/a
Experiment	n/a
Financial matters	n/a
Future visions	n/a
Growth	n/a
Informality	n/a
Innovation	n/a
Instruments	n/a
Knowledge	n/a
Local law	n/a
Metering and measuring	n/a

Motivations	n/a
Public Participation	n/a
Skills	n/a
System design (and technologies)	n/a
Targets	n/a
Technology Narratives	n/a
Timescales	n/a
User	Commercial users, Energy cost, Housing association, Involvement, Motivation, Perception, Practice, Satisfaction
Visibility	n/a
Water regulation	n/a
Weather and climate	n/a

CONTEXTUAL CODING

1st level	2nd level	3rd level
National level	n/a	n/a
Social structure	Middle classes	n/a
	Poverty	n/a
	Upper classes	n/a
Actors	Academia	n/a
	Government Local	n/a
	Government National	n/a
	Government Regional	n/a
	International influence	n/a
	Markets	n/a
	Networks	n/a
	NGOs	n/a
	Private sector	Builders & construction industry; dealer; ESCO; importer; installers; manufacturer; system designer; utility companies
	User	n/a
Urban	Agenda	n/a
	Infrastructure	n/a
	Planning	n/a
	Retrofit	n/a
	Structure & location	n/a
	Agenda	n/a
	Infrastructure	n/a
	Planning	n/a
	Retrofit	n/a
	Structure & location	n/a
	Agenda	n/a
	Infrastructure	n/a

Appendix IV

List of non-academic outputs aimed at practitioners

NON-ACADEMIC OUTPUTS AIMED AT PRACTITIONERS

Publications prepared for ICLEI-Local Governments for Sustainability, South Asia office (based in Delhi, India):

- Case study "Thane, India: Pioneering India's Solar Cities Program" (2012). The case study is part of ICLEI's Case Study Series with are widely used by local governments all over the world. Available here: http://www.iclei.org/fileadmin/PUBLICATIONS/Case_Studies/ICLEI_cs_142_Thane.pdf [Accessed 29 September 2013]

- Contribution to the publication "Local Sustainability 2012 – Showcasing Progress" (2012). This document was launched and widely distributed during the United Nations Rio+20 conference in Brazil. Available here: http://local2012.iclei.org/fileadmin/files/LS2012_CASE_STUDIES_www.pdf [Accessed 29 September 2013]

Report for Vitae Civilis, São Paulo, Brazil:

- "Proposed additional text for the report 'Boas Práticas em Energia Solar'" (Vitae Civilis/GIZ; version Nov. 2011). This report feeds into how the organization promotes the use of solar hot water systems in Brazil. It provided input to a project funded by the GIZ on best practices on solar technologies.

Other publications aimed at practitioners:

- Article for the UN-Habitat magazine Urban World: "India pioneers use of solar power in city of Thane" (Oct. 2011). Available here: http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3214 [Accessed 29 September 2013]

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