Assemblages of solar electricity: enacting power, time and weather at home in the United Kingdom and Sri Lanka

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Abstract

This thesis explores what happens to the social enquiry of the powers of energy, if energy technologies and electricity are taken seriously as actants. It questions how photovoltaic solar panels and solar electricity act in everyday lives in domestic homes and how a more material enquiry of them can help shed light on the ways in which photovoltaic technology is made to matter in different places. It proposes to contribute to the social enquiry of energy by providing an example of how the power of electricity can be investigated and analyzed as a contingent achievement of particular assemblages rather than a neutral resource and affordance.

Photovoltaic solar panels are enrolled in global discourses of environmental governance and sustainable development, and are employed not merely to generate electricity but also to have particular social powers: they generate electricity in different quantities and for different socio-political purposes in different places. As solar photovoltaic technology has gained momentum as a renewable energy technology that can be scaled and adjusted to fit different local and global matters of concern, it has also increasingly become part of different domestic homes, where it provides small portions of power for individual householders to use. This thesis considers two empirical settings where micro-generation solar is at work: in efforts to provide electricity to rural households in Sri Lanka and in efforts to reduce carbon emissions from households in the United Kingdom. The thesis argues that a tendency to focus on diffusion and social acceptance of solar in both policy and research has left gaps in our understanding of how solar works as a material force in everyday life after installation. The thesis engages with theories of assemblage and material agency and argues that the sustainability or greenness of domestic solar power should not be considered an attribute of the technology, but rather seen as the achievement of a particular socio-material assemblage. It offers insights into how domestic solar is assembled and illustrates how solar electricity acts not as a neutral resource, which is handled and interpreted by human beings but rather as a spatially and temporally diverse force with properties and propensities, which encourage particular orderings of meaning and matter.

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Abbreviations

DECC: Department of Energy and Climate Change

DNO: Distribution Network Operator

ESD: Energy Services Delivery Project

FIT: Feed-in Tariff

kW: kilowatt

kWh: kilowatt-hour

kWp: kilowatt Peak

PV: Photovoltaic

RERED: Renewable Energy for Rural Economic Development

SHS: Solar Home System

WB: The World Bank

Wh: watt-hour

1 Introduction

Figure 1-1: Power from the sun (image from www.mainframegroup.net)

"It's like a gift from cosmos" (Mark, Solar PV owner, December 2011)

1.1 Energy, environment and the home

Issues of climate change and sustainable development have become positioned at the very top of international political agendas and enrol a large and complex assemblage of actors which include civil society, multilateral development banks and market based organisations which are now involved in their governance (Bulkeley and Newell 2010).

Energy use and the properties of different kinds of fuels are at the heart of this as issues of energy and climate have become intrinsically linked and energy has converged with climate change on both international and UK policy agendas. Although the links between environmental and energy issues have become strong, there is good reason to still be curious about this convergence, particularly as discourse is translated into material reality (Lovell, Bulkeley et al. 2009). References to environmental impact, now almost obligatory in introductions to energy policy announcements as well as academic publications indicate how these are discursively bound together. However, on an empirical, domestic, everyday basis, there is some evidence that the two might not sit together quite so smoothly out there, in 'material reality'.

This thesis relates to a growing body of work within geography, sociology, anthropology and cognate social science disciplines which is curious about this, not merely the question of how energy and environment relate to each other but particularly how individual human beings fit into this equation. As the links between energy and environment have become stronger over the last few decades they have enrolled a particular discourse which has been concerned with changing individuals' attitudes to environment in order to influence them to use energy differently, a discourse which has been referred to as the "going green" discourse (Moloney and Strengers 2014) or the "ABC – Attitudes-Behaviours-Choice – Paradigm" (Shove 2010). A by now large body of international literature has been highly critical of this particular assemblage of energy, environment and individual human beings and noted already a decade ago that "the remarkably rapid increase in public awareness of environmental issues and embracing of pro-environmental attitudes is coupled with virtually no substantive changes in behaviours at all" (Burgess, Bedford et al. 2003).

In other words, changes to individuals' knowledge about *environment* do not seem to have had convincing impact on their uses of *energy*. This problem with the relationship between knowledge about climate change and domestic uses of energy is still problematic today and not an exclusively academic matter of concern. When the findings of a study commissioned by the Department for Energy and Climate Change looking at *"Savings, beliefs and demographic change"* (Palmer, Terry et al. 2014) made it into the national news stream in 2014 The Telegraph ran an article under the headline *"People who claim to worry about Climate change use more electricity"* (Holehouse 2014). Peter Lilley, a Conservative member of the Commons Energy and Climate Change committee, was quoted for saying that:

> *"The survey exposes the hypocrisy of many who claim to be 'green': the greater the concern people express about global warming the less they do to reduce their energy usage."* (Peter Lilley, MP, 2014)

The Daily Mail went further with the title: *"Are climate change zealots hypocrites? People who claim to be worried about global warming use MORE electricity, says study"* (Zolfagharifard 2014). This kind of discourse does not only rely heavily on the explanatory framework of the 'ABC paradigm' mentioned above, it also employs a particular morality in relation to the issue: are people who worry about climate without saving electricity hypocrites? Are their worries about the environment insincere? The heart of the issue it appears from these articles lies in the hearts and minds of individual human beings, making the next logical step one of blaming the consumers (Evans 2011) who have the morally good concerns about climate change in one hand and morally bad habits of energy use in the other.

If information and even worry about climate change does not lead people to make significant changes to their energy uses despite the two being so closely connected discursively, this poses a number of interesting questions about how the two relate to each other out there, in the homes and everyday situations where energies are in use: In what way do the ways in which people use electricity in their everyday lives connect or relate to the way in which they worry about the environment? And could this be investigated in a manner, which avoided the anthropocentric lens of the ABC paradigm, and without necessarily framing the individual consumer as the sole culprit?

This thesis aims to do so. More specifically it aims to explore what happens to the social enquiry of the powers of energy, if energy technologies and situated flows of electricity are taken seriously as actants. If electricity was not merely something which human beings used or consumed, but also a source of agency, the question would no longer be whether people were sincere in their worries about climate in relation to their daily energy uses, but more materially: whether they have the (electric) *power* to connect the two in everyday activities.

In order to be able to engage with this question, it is useful to consider what kind of situations or frameworks daily energy use and worry about climate change exist in, and how they relate to each other. One way to look at this is to consider the former a local enactment and the latter a global one.

1.2 A power to connect local and global?

It has been noted that as the willingness to address issues of sustainability and environmental governance has grown globally in the last 30 years, multiple enactments of earthly politics have come to balance, redefine and challenge notions of 'the global' and 'the local' in many ways and in many places (Jasanoff and Martello 2004). Key publications in the tradition of Science and Technology Studies and related traditions have addressed this question of how small domestic acts relate to big global issues (Latour 1993, Jasanoff and Martello 2004, Ingold 2011). An important insight from this work is that the notion of the global, as iconically illustrated by the image of planet earth captured by the cameras of the US space program, is meaningful only insofar as it erases the very different day-to-day lives of people. The planet earth, it is argued "promises an imagined community as encompassing as the earth itself, but is this a community in which those without the power to patrol the heavens, to map and perhaps devastate the earth, can ever meaningfully participate?" (Jasanoff 2001 : 30). The curiosity about the inherent difficulties which arise when "the impersonal, apolitical and universal imaginary of climate change projected by science comes into conflict with the subjective, situated and normative imaginations of human actors engaging with nature" (Jasanoff 2010 : 234) lies behind this thesis. Tim Ingold has considered the question of how we are accustomed to imagine the relationships between human beings and the earth and suggests that

> "We are, I think, inclined to forget that the environment is, in the first place, a world we live in, and not a world we look at. We inhabit our environment: we are part of it; and through this practice of habitation it becomes part of us too" (Ingold 2011: 95)

Understanding the environment from the point of view of someone who carries out their everyday life in it, is not the same as understanding it from a point of view obtained from outer space. But this is not merely a question of different viewpoints or perspectives on essentially the same entity, but rather a situation of multiplicity, of different modes of engagement and ordering: "whereas the globe is measured and recorded, the environment is experienced. One has climate, the other has weather" (Ingold 2011: 96).

With the increasing urgency of man-made climate change and sustainable development, and the growing concern about the impact local everyday energy uses have on the global climate, throughout the last 3 decades the search has been on for different means of providing connections between the home and the globe. This has taken different forms, from information campaigns, financial incentives or different technologies in order to alter and reduce domestic energy consumption (Hinchliffe 1996, Hobson 2006, Marres 2009).

Solar panels are an example of such a technology, an intermediary which orders and translates otherwise difficult-to-grasp phenomena such as electricity, sunlight, clouds and carbon to name only a few. But this translation is not neutral, and it assembles and arranges more than protons, electrons and carbon dioxide. The field of science and technology studies in the last 3 decades has been enquiring about and illuminating the ways in which environments and climates become knowable to people through the intermediary of the sciences, that people know climate through interventions of *professions, disciplines, and protocols* which arrange and distribute both what climate *is* and how it can be known and lived with (Latour 2004: 4). Devices such as solar panels are therefore also political: ways of knowing the world are inseparably linked to ways of ordering and controlling it (Jasanoff 2004). Micro-generation solar panels construct and enact domestic everyday life and global climate *in a particular way*. Because of this they provide a useful site for exploring the concerns of this thesis.

1.2.1 Political panels

Solar panels, domestically installed ones in particular, are then an example of a technological device and a political intervention which it is now hoped might help forge sustainable relationships between domestic households and global climate. This was not always how solar panels were framed however. Tracing the history of solar photovoltaic electricity in the UK over the last 40 years, Smith, Kern et al. (2014) have shown that whilst the research, development and use of PV electricity can be traced back to the 1970s politically it was not considered a relevant technology for the UK for many years. Discourses about climate change and green economy were not what initially motivated research into photovoltaics and were not always politically attractive. Only after nearly four decades of increasing advocacy amongst governmental opposition did growing concerns for climate change enable a space and political support for PV, not least as it came to enrol politically popular notions of micro-generation (Smith, Kern et al. 2014). Similarly in Sri Lanka and other developing countries solar panels became not only technically appropriate for producing small amounts of electricity in areas where electricity grids were not considered capable of reaching, but also politically appropriate for multilateral institutions such as the World Bank and the Global Environment Facility who needed to invest in green technologies (Miller 2011). Whilst climate change discourse might not have been the condition of possibility for solar photovoltaics it was what eventually came to give it global political support and technological momentum (Hughes 1983).

As such domestic solar panels provide a rich site to explore the relationship between (local) situated everyday experiences and (global) scientific and political imaginaries: enacting solar panels it became assumed may assemble the global in the local. This thesis is curious about how that works in everyday life, not just rhetorically but also materially. Investigating this involves getting to know solar panels, not just as an object of interpretation and politics, but as a political actant, as a power.

1.2.2 Technological and material politics

A solar panel is a technological device, which has the capacity to transform sunlight into electricity without emitting carbon dioxide into the atmosphere. Solar panels are furthermore a scalable and flexible technology, which makes them suitable devices in many contexts, including domestic homes in different geographical locations and within different existing energy systems. These properties do not just enable them to generate electricity in most places, they are also very important reasons for why solar panels are capable of assembling a number of the political and financial interests relating to the assemblage of actors involved in the global environmental governance discourse mentioned above (Cross 2013). These multiple capacities and powers of solar panels have earned them something of an environmental "gold star" (Hobson 2013) as a green and sustainable energy technology which has enjoyed the support of both national governments and international organisations.

This support has enabled the global market for solar to develop rapidly in recent years. The worldwide growth of photovoltaics has thus fitted an exponential curve for more than two decades and developed from a niche technology towards becoming part of mainstream electricity. By the end of 2014, cumulative photovoltaic capacity had reached at least 177 GW, sufficient to supply 1 percent of the world's total electricity consumption of currently 18,400 TWh. (IEA 2015). Forecasts for 2015 suggest a further increase of 35 to 53 GW(EPIA 2014). In the UK alone a total of 650,000 solar installations with a capacity of over 5,000 MW of solar power was reached in 2014, enabling the UK to overtake Germany as European PV market leader (DECC 2015, IEA 2015).

As solar panels make their way to different locations, many of which have been domestic households, they become part of different modes of ordering both flows of electricity and social life. They become actors in what Science and Technology Studies scholars refer to as "the untidy, uneven processes through which the production of science and technology becomes entangled with social norms and hierarchies" (Jasanoff 2004: 2) or they come to perform what Annemarie Mol refers to as ontological politics: "a politics that has to do with the way in which problems are framed, bodies are shaped, and lives are pushed and pulled into one shape or another"(Mol 2002: viii)

Although this political entanglement is predominantly considered external to the workings of technologies within techno-science (Wilhite, Shove et al. 2003), it has been suggested that that this assumed capacity of devices to *do more* or to influence the manner in which people order their everyday lives are increasingly becoming part of the political considerations that put particularly designed technological devices 'out there' in domestic households (Akrich 1994, Marres 2012, Smith, Kern et al. 2014). Solar panels are such a technology, which has become enrolled in the 'going green discourse' and given political support partly because it is assumed that they, through a particular entanglement with social life, may help perform a certain kind of social engineering: have the 'added benefit' of making people use and make sense of energy differently (Dobbyn and Thomas 2005).

But as Jasanoff stated above, this is an untidy and uneven process. Trusting technological devices to do this sort of job involves a margin of error (Marres and Lezaun 2011). Things do not always go to plan when devices are put to work in this manner. There are many explanations for this. Most of these explanations emphasize the different ways in which human beings at different stages interpret and engage with the technology, its design and its everyday use. Often it has been suggested that this is because people don't do what they were expected to, that they do not have all the facts or a thorough enough understanding of flows of energy to do the right thing (Owens and Driffill 2008) or that they simply can't see them (Burgess and Nye 2008). Other explanations suggest that there are sometimes problems with the way the everyday lives of these people are imagined by the energy industry and policy makers (Cotton and Devine-Wright 2010, Walker, Cass et al. 2010, Barnett, Burningham et al. 2012).

Distributed agencies are in other words involved in this process (Bennett 2005) and whilst the existing literature is already aware of this, this thesis proposes that it has been predominantly concerned with distributed *human* agencies, leaving out questions of what devices such as solar panels and forces such as solar electricity do. Appreciating how devices have both social lives (Appadurai 1988) and specific although indeterminate qualities (Braun and Whatmore 2010) and how flows of electricity have both vibrant agency and political power (Hughes 1983, Bennett 2010, Mitchell 2011) enables a contribution to these knowledges. Particularly it enables an alternative analysis and explanation which does not focus on blaming the consumer (Evans 2011 see also Bennett 2010).

Scholarship on energy practices in the last two decades has made significant inroads to understanding how social uses of energy develop or change, not merely as a matter of individual choice but as a result of larger social practices (Shove 2003). This rapidly expanding body of work offers inspiration for this thesis particularly as it has been increasingly telling us that we need to understand how energy forms part of assemblages of meaning and matter, which go beyond the domestic household (Shove 2003, Wilhite, Shove et al. 2003, Ropke 2009, Gram-Hanssen 2011). Microgeneration solar panels however appear to move in the opposite direction: they bring the complex and distributed issues of energy supply and demand, carbon emissions and sustainable development home (Aune 2007) and make them a domestic issue. They then form part of the going green discourse already mentioned and follow the by now well-rehearsed trope that 'helping the earth begins at home' (Hinchliffe 1996), through which responsibility for these complex issues is individualised and the point of political intervention thus becomes centred on the individual consumer as the both the vehicle for and the obstacle against social change (Maniates 2001, Hobson 2013).

Whilst this thesis agrees that the question of how domestic everyday uses of energy come into being and become meaningful to human beings is central to understanding energy demand and energy transitions (Spaargaren, Martens et al. 2006, Shove and Walker 2010, Gram-Hanssen 2011) it is particularly interested in investigating the agencies of energy devices and flows of electricity (Marres 2012).

1.3 Different assemblages and different powers

The scalability of solar PV enables it to become enrolled as a suitable technology in different locations and within different socio-material assemblages. The capacity to generate electricity from sunlight has thus enabled solar panels to become enrolled in different socio-political matters of concerns across geographical locations. This thesis is curious about how the scalability and flexibility of solar comes to play itself out when solar panels are made to matter differently particularly in relation to climate change and carbon emissions in one part of the world and in relation to international development and electrification in other parts of the world. It investigates this by investigating solar panels in use in two locations: the UK and Sri Lanka.

In the context of the UK, solar panels and in particular microgeneration solar were given significant political support when the Feed-in Tariff was introduced in the UK in 2010, causing a significant growth in the solar industry as domestic solar installations were made a good investment for individual households, not least due to a perceived potential to draw links between global climate and domestic energy use (DECC 2010, Mendonça 2011, Smith, Kern et al. 2014), which made solar panels not only a green energy technology but also a bank on the roof. This political support follows the notion that microgeneration solar might be not merely a technically efficient model for energy distribution but that it may also provide a bridge between energy supply and demand and thus lead to changes to domestic energy consumption (Dobbyn and Thomas 2005, Keirstead 2007, Bergman and Eyre 2011).

The question of the capacity of solar panels to do more than generate electricity has thus achieved some attention, but focus has been predominantly on uptake (Bergman, Hawkes et al. 2009). Strategies to maximise uptake however will not suffice in order to maximise energy and emission savings (Bergman and Eyre 2011, McCormack and Norton 2013, Price, van der Linden et al. 2013) on the one hand and may on the other hand potentially encourage practices which either simply sustain consumption at current levels (Lovell, Bulkeley et al. 2009) or which become undesirable in the longer term (Janda 2007, Keirstead 2007, Bergman, Hawkes et al. 2009).

In the context of Sri Lanka, solar was employed in efforts to bring electricity to households in out of the way places, in the World Bank and Global Environment Facility supported Renewable Energy for Rural Economic Development project, which ran from 2002 to 2011. The project was successful in distributing a large amount of solar panels as part of domestic Solar Home Systems in this period, by arranging the power of solar also here as a domestic affordance translating, it has been argued, electricity into an individual consumer good (Cross 2012, Cross 2013). Literatures considering solar panels in this context have been concerned with questions of how solar panels relate to economic development and rural electrification, what enables them to succeed or fail in their efforts to travel to rural households and stay there and whether this is the right and just thing for them to do (Nieuwenhout, Van Dijk et al. 2001, McEachern and Hanson 2008, Laufer and Schafer 2011, Miller 2011, Bickerstaff, Walker et al. 2013, Palit 2013).

Seen together these two different bodies of work ask both similar and different questions of solar panels, and provide different conceptualisations of what solar panels 'have something to do with' (Law 2002, Haraway 2008). The interferences between the different framings and uses of solar technology are useful to unpack, in order to establish how and what solar panels situated in domestic households have to do with issues such as energy consumption, global climate change, sustainable development and quality of life.

Reiterating the curiosity about what solar panels then do in people's houses in the light of these insights this thesis proposes that more attention to how different and situated meaning relates to different and situated power provides a useful means of producing knowledge, which can contribute to making possible different enactment of energies. Greater curiosity towards energy as energy or as vibrant materiality and agency (Bennett 2010) it believes can help shed light on how particular flows of energy do not just become the resource for and object of multiple practices and politics but contribute actively and sometimes ambiguously to the shaping of material-discursive pathways. This enquiry involves questions of how different ontologies, scales and kinds of knowledge and meaning become entangled in everyday lives and in particular how meaning and power relate to each other.

This line of questioning connects with a body of Science and Technology Studies scholarship which has argued that the material powers of energy matter, that energy is not a neutral resource, but that particular powers shape particular societies and social orders (Hughes 1983, Nye 1990, Hecht 2009, Mitchell 2011). This thesis proposes that insights provided by this body of work can be usefully put to work in an understanding also of domestic solar electricity. .

1.4 Research Aims

This thesis aims to explore what happens to the social enquiry of the powers of energy, if energy technologies and flows of electricity are taken seriously as actants. It questions how local assemblages of solar electricity act in everyday lives in domestic homes and how a more material enquiry of them can help shed light on the ways in which photovoltaic technology are made to matter in particular ways in particular places.

It aims to carry out an enquiry of solar assemblages in domestic homes in the UK and in Sri Lanka, asking in particular what these power and assemble or what they have 'something to do with' in everyday life. In doing so it aims to contribute to a more decentred and heterogeneous enquiry of domestic energy consumption that provides an alternative analytical framework to that of 'blaming the consumer'.

It proposes to contribute to the social enquiry of energy by providing an example of how electricity can be conceptualised and investigated as a lively and contingent achievement of particular assemblages rather than a neutral and universal resource and affordance.

1.5 Structure of thesis

In the following chapter (Chapter 2) I situate the empirical and theoretical themes of this thesis in existing literatures and account for how they have shaped the concerns of this thesis. I suggest that whilst existing literatures on domestic energy uses have provided important insights into everyday uses of energy in the last three decades, these have predominantly been concerned with how different groups of human beings interpret and handle flows of electricity in different positions and struggled to include the material agency of energy *as energy* and power.

The chapter proposes that an assemblage-based approach, which investigates solar electricity as a particular power within domestic homes, can contribute to new understandings of the meaning-matter of different energies. The chapter further suggests that there are some potential gains from enabling a focus on solar panels to travel across both empirical and conceptual boundaries. It therefore proposes a combined enquiry of solar panels in use in the UK and in Sri Lanka as a means of disturbing existing understandings of what solar panels have *something to do with*, and move towards a greater curiosity towards and engagement with electricity as material force and as the achievement of a particular assemblage

In Chapter 3 I introduce the methodological framework of the thesis. I suggest that an enquiry which wants to bring out the vibrant materiality and agency of solar panels and solar electricity in domestic homes must enable itself to capture not just meaning but also the particular capacities and properties of specific powers. This chapter argues that an ethnographic enquiry of solar assemblages and everyday enactments of solar electricity with a particular emphasis on distributed and non-human agencies provides a promising means of doing that..

Following the suggestion to consider everyday enactments of solar electricity, the chapter illustrates a number of methodological issues and difficulties, which occurred in the process of doing this research. It suggests that greater attention to how ethnography is done, situated and adjusted affords a critical engagement with the activity and enactment of ethnography and proposes that notions of collaborative experimentation provide a better explanatory framework for what happens *in the field* than the more familiar notion of “data collection”.

Chapter 4 is primarily concerned with how to approach solar panels and solar electricity as actants, whilst remaining within the boundaries of social enquiry. It suggests that a certain tooling up in order to appreciate the details of how solar panels work is a useful means to developing abilities to ask questions of the material capacities of solar panels and that this can come from curious engagement with the manner in which solar panels are enacted and made sense of in other disciplines, predominantly techno-science. The chapter then continues to describe how the properties and propensities of solar panels are made to matter through multiple external circuits and knowledge practices and how the situated powers, which emerge from their specifically shaped capacities, invite particular enactments whilst preventing others.

Chapter 5 moves on to consider what the properties, propensities and entanglements of solar can achieve in domestic homes in the north of England. In this chapter I demonstrate how the properties of solar electricity contribute to particular uses and modes of ordering it as a specific rather than a neutral or general domestic affordance. I show how the daily and seasonal patterns of generation come into conflict with daily and seasonal patterns of electricity consumption and how this difference becomes performative, and consider how contingent heterogeneous assemblages come to create a specific kind of domestic electricity.

Chapter 6 investigates how solar panels are assembled in the context of everyday enactments in households in rural Sri Lanka, as components in Solar Home Systems distributed by the Renewable Energy for Rural Economic Development project. This chapter shows how the indeterminacies and entanglements of solar panels in this assemblage come to act and shape both everyday enactments of different kinds of energy use and the material capacities of solar electricity. Differences between local notions of electricity and solar as everyday affordances are considered in order to provide an understanding of the socio-material capacities of Solar Home Systems in domestic use and as part of wider networks of different powers.

In Chapter 7 I pull together the themes considered in the previous chapters to show how domestic solar can be re-assembled and understood as a power of 'more than one but less than many' (Law 2002). I propose that enquiries of the vibrant agencies of solar assemblages can help open up new entry points and frameworks for understanding domestic energies-in-use on the one hand and relationships between meaning and power on the other hand. Finally I suggest further avenues of research following the insights provided by this thesis.

2 Literature review: Assemblages of power and the material agency of solar panels at home

2.1 Introduction

In this chapter I outline the conceptual underpinnings for an enquiry into everyday enactments of PV technology in domestic use, specifically crystalline silicon solar panels, in the north of England and in rural parts of Sri Lanka. Solar panels are, as outlined in the introduction, already framed in particular ways in particular contexts: they are not merely energy generating devices; they are devices which generate energy in particular ways, used for particular purposes.

PV devices, which make electricity in a particular way, are not neutral, and they are not context-independent. In literatures, which are concerned with material agency such as Science and Technology Studies and related fields of enquiry like the Philosophy of Technology, this is a basic assumption. It is not however a basic assumption everywhere. Peter-Paul Verbeek has usefully pointed out how two "common-sense" approaches to technological artefacts often frame the discussion of them: The first one which he calls *instrumentalist*, sees technologies as neutral means of achieving human goals, whilst the second, the *substantivist* conception considers technology not neutral but determining and controlling of society and culture (Verbeek 2005: 11). This thesis relies on a different understanding of what artefacts and materials do, which is an understanding this literature review sets out to introduce and develop specifically in relation to solar panels in particular places.

The chapter progresses as follows: Section 2.2 situates the concerns of this thesis in relation to recent efforts to conceptualise and investigate domestic energy use. Sections 2.2.1 and 2.2.2 outline the two literatures relevant to social enquiries of solar panels in the UK and in Sri Lanka respectively and draw out the dominant framings and conceptualisations in these as they are organized around concerns about energy consumption and rural economic development. In section 2.3 I introduce an alternative analytical approach to the enquiry of solar panels seen through concepts of materiality, assemblages and the home and ask what happens when solar panels act. In section 2.3.1 I consider firstly the merits of "taking materials seriously" as active agents in social analysis. I then suggest in section 2.3.2 that the concept of assemblage provides a useful framework for considering how devices and materials act. Section 2.3.3 further explains why I feel that related concepts of intra-action and enactment offer a useful means of investigating solar assemblages through focus on the everyday agencies of solar panels. In section 2.3.4 I finally consider the merits of considering the setting of the home as an analytical plateau for understanding the achievement of situated powers, before concluding the chapter in section 2.4.

2.2 Solar Panels in different places, and the problem at the end of the pipe

> "What might, through other kinds of lenses, be seen as coherent, similar kinds of force being in operation, can through assemblage analysis be revealed to be heterogeneous, quite diverse situations with internal inconsistencies and idiosyncrasies" (Walker and Day 2013: 23)

Energy, this thesis suggests, is not the same force everywhere. And solar panels do not do the same jobs in the UK as they do in Sri Lanka. That technologies may do different things in different places is an assumption which scholars versed in the STS literature take for granted (Latour 1996, De Laet and Mol 2000). But as outlined both in the introduction and in this chapter so far, this is not a universal assumption. It is not uncommon for technologies like solar panels to be understood to work as *immutable mobiles* (Latour 1987) in a manner which is independent of the geographical location and social context they are placed in.

When energy in energy research and policy is often understood to be an immutable or neutral force, this is connected to the manner in which it has been traditionally investigated. A number of publications which have been concerned with the question of how social scientific energy research has developed particularly in the UK and other developed countries provides useful insights on this. Wilhite, Shove, Lutzenhiser and Kempton (2000 and updated versions in 2003, 2006) have outlined how the role of social science as a contributor to energy policy and energy related research following the energy crisis in the 1970s was dominated by an interest in the more or less energy efficient behaviour of end users. Separate to supply side research on technical devices and efficiency improvements within Physics and Engineering, social scientists became involved as 'people experts' (Henning 2005) in an effort to provide better understanding of the problem of human users interacting with energy flows, in order to improve the predictions of a device-centred modelling of energy efficiency (Wilhite, Shove et al. 2000). The authors have argued that the nature and causes of "energy demand" have been oversimplified, reduced or ignored in energy research and policy and that the limited role for social science, as authority on *behaviours* and *end-users* has resulted in very little understanding of how energy demand works as a social (as opposed to individual) phenomenon (Wilhite, Shove et al. 2006 see also Owens and

Driffill 2008). This has further resulted in a "yawning gulf between the potential contribution of the social sciences and the typically restricted models and concepts of social change embedded in contemporary environmental policy in the UK and in other countries too" (Shove 2010: 127).

Following these insights calls have been made to abandon this research agenda which it is said has been "stubbornly reliant – despite two decades' evidence of programs which fail to live up to expectations – on a view in which human "behaviour" remains conceptually distinct from the workings of devices, buildings, infrastructures and the other socio-technical arrangements involved in energy use" (Wilhite, Shove et al. 2000 see also Shove 2010, Shove and Walker 2014), and replace it with one which tries to avoid the two dominant dichotomies that have shaped the field so far: the separation of supply and demand, and the separation of technology from human beings. Although this challenge is taken up differently and to varying degrees in different literatures and in relation to different geographical locations, it is an important part of many current attempts at conceptualising energy use, and an important influence on this thesis. In responding to this challenge this thesis is inspired by literatures which have approached this challenge through an enquiry into social practices of energy use, but maintains a particular curiosity about details of material and distributed agency, or the so-called material element of social practices (Shove 2010). This thesis chooses assemblage thinking as an alternative to the "classic" device-centred approaches within physics and engineering which focused on the energy efficiency of devices in a manner which saw human engagement with devices as external or irrelevant at best or unpredictable and problematic at worst (Wilhite, Shove et al. 2006). It follows the contention recently put forward by Tania Murray-Li, that "Exposing the apparent naturalness of a resource assemblage renders it made-up character available for critical reflection (Li 2014: 590)

This thesis therefore proposes that there is much to be gained from refusing to see solar electricity as a natural resource whose power is separate from what human beings can achieve with this power and suggests that drawing on the insights Science and Technology Scholars have on how technological devices operate in society can provide a lens through which 'energy consumption' might not be a coherent or consistent phenomenon or meta-narrative which is cleanly reproduced in different places, but rather a situated and contingent achievement (Gregson and Crang 2010, McFarlane 2011)

One useful way of investigating the manner in which solar panels work is to consider them not neutral or context-independent but rather as situated or what STS refers to as 'mutable mobiles': things that travel to different places because of an ability to 'change shape', also sometimes referred to as fluid technologies (De Laet and Mol 2000, Law and Mol 2001). To do that it is interesting to look at how they work in different places. This thesis has chosen two such places: the UK and Sri Lanka. In choosing two such different places it wants to signal that curiosity here is not about evaluating deployment of solar panels in order to suggest a 'best practice', but rather investigate how solar panels assemble or are assembled: how they come to do different things for different reasons in different empirical places.

The following two sections look at the manner in which solar panels have been questioned in different ways in relation to their uses as domestic devices in the UK and in Sri Lanka. They are concerned not merely with what solar panels in the two places have been found to do or not do, but rather how they have been investigated as they have become enrolled in different concerns in the different literatures, or have 'something to do' with different socio-material assemblages.

2.2.1 Solar panels in the UK: Energy consumption and behaviour change

Whilst both policy initiatives and the majority of social research on solar has tended to focus on distribution and uptake of the technology (Bergman, Hawkes et al. 2009), the potential for domestically installed solar PV to bring about changes towards more pro-environmental behaviours, most specifically reduction in energy consumption, has received some attention in the last decade (Erge, Hoffmann et al. 2001, Dobbyn and Thomas 2005, Munzinger, Crick et al. 2006, Watson, Sauter et al. 2006, Bahaj and James 2007, Keirstead 2007, Watson, Sauter et al. 2008, Bergman, Hawkes et al. 2009, Abi-Ghanem and Haggett 2010). This potential for behavioural change as an added benefit of specifically microgeneration solar (Keirstead 2007), has led some researchers on PV users in the UK to suggest that "The potential contribution of micro-generation should be assessed not just in relation to its generation capacity but to its potential as a catalyst for urgently-needed behaviour change" (Dobbyn and Thomas 2005)

The findings from the research into this question however are not clear cut, ranging from positive findings of energy reduction in some studies (Keirstead 2007), to findings of an increase in energy consumption in others (Bahaj and James 2007) (se also review of other existing research findings in (Keirstead 2007). This uncertainty in relation to whether solar PV encourages people to use more or less energy, suggests that the social or 'mediating' power of solar panels is a complex issue and is one reason why some critics have questioned whether the political framework chosen for the employment of solar electricity is potentially leading us down a path that leads us to consume more (solar) energy, rather than to use energy more wisely (Janda 2007) and related to this, whether household PV can provide more than marginal emission abatement whilst consumers remain dependent on 'less than green' energy sources for reliable electricity (Palmer 2013), both critiques which point to a need to understand better what happens to flows of electricity beyond the household.

Although the question of interaction between human beings and domestic PV technology has primarily been approached with the question of whether an added benefit could be measured, some qualitative questions have been asked. Studies which have adopted more qualitative approaches have tended to conceptualise the differences between different modes of engagement with PV technology as a result of different kinds of people or personalities (Dobbyn and Thomas 2005) or user types, some more interested in the technology or more motivated towards environmental change than others (Abi-Ghanem and Haggett 2010). Whilst this work recognises the socio-technical nature of these issues, it retains human understanding at the centre of the analysis, asking 'how is solar energy interpreted and understood by different human beings' rather than what do they do with it? More recent studies however have begun pointing to a need to understand the temporalities and diversities involved in using low carbon energies in the home and to question in more detail when people use what services, and indeed how some energy uses are flexible whilst others are not (Powells, Bulkeley et al. 2014, Walker 2014).

An increased attention to what (solar) power is for and when it is used (Shove and Walker 2014) enables a step further from the more quantitative question of how much energy was saved or used differently and enables the question of whether human beings were inclined or able to save electricity or not, to become qualified with the question of how it was done. Concluding that a "double-dividend" from PV does indeed exist, Keirstead reported an estimated 6% reduction in overall energy consumption (Keirstead 2007). What those 6% represented in terms of practices however, if it was the result of solar electricity replacing a small portion of base-load energy use or if it was the result of different energy use patterns, like reduction in the use of certain lights or TV or tumble driers, or even if it was down to factors like a milder winter is unknown. This is not a trivial question, particularly not as other research findings report an increase in annual consumption. The question of what a 6% saving in one study or an increase of overall consumption in another study might translate to in terms of everyday energy consumption practices, or which particular uses of energy might become affected by the introduction of solar electricity, which devices might get used differently or less, is a question which still needs more attention (Powells, Bulkeley et al. 2014). This involves greater curiosity towards the details involved in living with solar PV, and the ways in which users and the technological devices meet and build relationships and practices that evolve over time (Gregson 2007, Shove, Watson et al. 2007).

Whilst the literature directly concerned with domestic solar PV has not yet provided much information on this, some studies have investigated the quotidian deployment of other 'green' technological devices such as energy saving light bulbs (Crosbie and Guy 2008) bins and shower timers (Hobson 2006). Of particular interest to this thesis is research which has been done on household experiences of smart meter technology, as this provides relevant insight into how people engage with domestic energy technologies in both UK homes and homes in Australia (Burgess and Nye 2008, Hargreaves, Nye et al. 2010, Strengers 2011). Based on interviews with participants in a UK smart meter trial, this research investigated the manner in which householders engaged with smart meter technologies and the information they provided. Focusing in particular on impact on levels of consumption this research found this to be limited, particularly after the initial novelty effect began fading, as people either became complacent or reached a level of change beyond which they did not feel able to reduce their consumption any more (Hargreaves, Nye et al. 2010). What is of particular interest to this thesis however is that other than the relative impact on levels of energy consumption, smart meters were found to impact on something else, namely the manner in which members of the household attached meaning to energy flows following the information provided by the smart meter, causing both arguments and anxieties about flows of energy. As new practices of shame and blame followed the increased awareness of energy flows and in particular the financial consequences of these, it led Tom Hargreaves to comment that "whilst these devices may help reduce electricity consumption, they may also increase the divorce rate" (Hargreaves 2011 : 36). What this throwaway comment indicates, is that questions of what is internal and external to the working of technologies like smart meters and PV systems might be a lot messier than assumed in the literature which considers changes to human behaviours an added benefit (Dobbyn and Thomas 2005, Keirstead 2007) and that the question of whether or not people save energy might be too narrow to capture the complexities around everyday engagement with devices and sources of power.

Whilst the capacity of solar panels to potentially 'do more' than generate electricity has been framed predominantly as a capacity to make human beings use less energy or consider energy in a different manner, the following section will show how these considerations are framed differently in studies about solar panels in Sri Lanka and related places. This is neither peculiar nor problematic as such: solar panels are employed to do different jobs and are thus evaluated according to these jobs. But what is important to notice in these literatures is how different questions are framed not about the capacity of solar panels, their power as power, but rather their power as added benefit or as capacity to engender social change. As solar panels travel to Sri Lanka, this added benefit is foregrounded differently: solar panels become development first, electricity next.

2.2.2 Solar Panels in Sri Lanka: electrification and Development

Seen in the context of their deployment in the developing world, Solar Home Systems in Sri Lanka become part of a literature, which is concerned with the evaluation of different efforts to provide electricity to un-electrified places. The main concern in this literature is whether Solar Home System electrification can be considered a viable technology for development in particular places (Wamukonya 2007), primarily based on research which has tried to establish on a case-study basis, which factors were important for the successes or failures of technology diffusion (Nieuwenhout, Van Dijk et al. 2001, McEachern and Hanson 2008, Miller 2011). It is in other words a literature which has been particularly interested in understanding which factors and contexts played important roles for the successful working of Solar Home Systems following different deployment models in different places, predominantly in relation to success criteria around improvements to quality of life and economic development (Nieuwenhout, Van Dijk et al. 2001). The complexity of providing clear cut evaluations of the impacts of these devices is clear in the case of Sri Lanka where a recent study pointed out that although many solar users would cite 'improved quality of life' due to better electricity, they would also point out that this was on a very small domestic scale with little or no impact on wider communities and a number of negative impacts from problems associated with loan repayments (Laufer and Schafer 2011), leading the authors to conclude that "If poor people have no access to productive activities in general, then increased access to energy is not likely to contribute towards poverty reduction" (Laufer and Schafer 2011: 335).

Although the majority of this literature seeks to establish best practice in terms of project management and systems of distribution, financing and maintenance, associated literatures touch on other questions, which it is useful to draw in. These relate to the economic potential of solar PV on the one hand and to particular ways of living with different devices on the other hand. The first literature focuses clearly on the market potential relating to the diffusion of renewable energy devices. This literature on the economic potential of 'Selling Solar' to emerging markets (Miller 2011), follows a socio-political imagination in which poor people in out of the way places are seen as capable consumers at the "bottom of the pyramid" (Prahalad 2009), a framing which has become increasingly prevalent in government and organisations like the World Bank (Jeffrey and Young 2014 : 184). This framing of PV users is important for the understanding of the movements and enactments of solar panels in Sri Lanka, because it enabled Sri Lanka to become considered a successful example of diffusion of Solar Home Systems, from both from the perspective of this literature and the perspective of the World Bank (Miller 2011). By framing diffusion as its main success criteria, the question of what happens after installation is almost absent in this lens. The ethnography carried out in this thesis however will go on to show that not only is this framing performative, it also rests on particular inclusions and exclusions. A large number of solar panels being sold in Sri Lanka it appears was very far from the same thing as a lot of happy customers (Palit 2013), which suggests that success criteria relating to the use of solar panels depend on a careful negotiation of keeping some things internal and other things external in evaluation.

The notion that devices such as Solar Home Systems, sold on an individual cash or micro-finance basis may be a promising technology for people living in out of the way places is a popular one. As Jamie Cross has illustrated in his paper about how the NovaS200 solar powered lamp became the 100th object in the British Museum and BBC's joint exhibition and radio documentary series (Cross 2013), solar lanterns are widely considered a life changing device for people living in un-electrified communities throughout Africa and Asia. As Cross shows, however, this is not solely a result of the way particular solar lanterns work, but because the solar lantern is capable of assembling a number of concerns and interests, politics, moralities and ethics (Cross 2013 : 369). This raises concern about a lack of critical reflection of this particular framing of products as humanitarian goods, and relates to a critical body of work which has asserted that devices such as Solar Home Systems are poorly understood without appreciation of the capability of solar cells to make themselves compatible with neoliberal policies and processes of capitalist accumulation (Luke 2005, Jacobson 2007, Thrift 2007, Wamukonya 2007). A key concern both in Cross's account of the NovaS200 and in the investigation of solar panels in this thesis, is the manner in which they become invested with the properties that enable them to gain such a prominent position in relation to these wider concerns. For Cross, who draws on the conceptual vocabulary of Michel Callon, the significance of objects like solar lanterns then comes out in their capacity to define and make economic markets (Cross 2013, see also Akrich 1994 and Callon et al 2007). Cross contends that

> "Bottom-of-the-pyramid markets in Africa and Asia for things like a low-cost solar light do not emerge: they are made. To think about the work that goes into making, imagining an constructing them demands a new engagement with their 'material politics' (Law and Mol, 2008) and a new engagement with humanitarian goods like the Nova S200" (Cross 2013: 385).

Cross' emphasis here on the distributed 'work' that goes into 'making' solar lanterns successful market devices is important for the questions in this thesis, because it helps foreground how the successes of devices such as solar panels on one hand rely on more than material capacity in order to become successful, and on the other hand often manage to avoid being questioned on exactly that point. This latter point is also the focus of Tanja Winther's recent work which has questioned how particular evaluation criteria come to leave certain parts of the story out, when considering the effectiveness of electrification programmes (Winther 2015). This leads this thesis to a curiosity towards the material capacity of solar panels, particularly what they come to do in and beyond the homes of people living in out of the way places (Tsing 1993), where the material capacity to do work is lived with in a more tangible manner than they are in the UK. If solar systems are 'out of order' in rural Sri Lanka, this has different ramifications for users there than it does for users in urban UK (Graham and Thrift 2007).

This leads to the second related subfield within development literatures relevant to this thesis, which is a body of work which is particularly interested in questions of how people (particularly in the context of South Asia) engage in practices of experimentation and improvisation, known as Jugaad which can be translated into the notion of 'making-do-and-mend' (Birtchnell 2011, Jeffrey and Young 2014). Accounts of Jugaad have shed light on how both materials, devices and infrastructures can be assembled in infinitely many ways and made to work in many ways, often very differently from what was intended or imagined (Jeffrey and Young 2014). This literature then illustrates the indeterminacy and fluidity (De Laet and Mol 2000) of devices like solar panels as they travel to different places. Although it is important not to embrace this phenomenon of creative improvisation uncritically and forget about the underlying social structures and negative consequences associated with it (Birtchnell 2011), the notion of Jugaad provides a useful framework for understanding how uses of technologies such as solar panels are not coherent and the same everywhere, but rather situated and contingent. Although Jugaad has been conceptualised predominantly in a South Asian context, it provides useful entry points to understanding the indeterminacy of solar panels also in the context of UK households. The notion of Jugaad or local improvisation although still primarily based on a human-centred explanatory framework provides more scope for understanding daily engagement with devices and uses of solar electricity as the result of more-than human networks. This thesis suggests that there is much to be gained by adding to the literatures outlined so far, an increased focus on non-human agencies and particular powers. The following sections consider how the enquiry of what devices and flows of electricity do could be extended in a more material manner.

2.3 When solar panels act: materiality, assemblages and the home

As the social scientific literature on solar panels is expanding in multiple directions as suggested above, new insights have been gained particularly on how to *get solar out there* and how to get human beings to consider them meaningful parts of their everyday lives. Connecting these insights with growing understandings of how energy is made to matter in social practices enables a different success-criterion in which greater attention is paid to what services solar panels can provide. A key consideration in this has to be an understanding of their material powers as they operate in everyday life. In this section I introduce the conceptual framework for an enquiry into solar panels as actants and explain why I feel that it is useful to address questions of domestic uses of solar panels in a way in which the agency and material vibrancy of solar electricity is given a more active part. In the first section I outline the notions of vibrant materiality and material agency, which inform this analytical approach. The second section explains how a situation of multiple material agencies and politics, which assemble and order both solar panels and everyday lives can be usefully investigated through the notion of enactment. In the third section I focus on 'the domestic' as a setting in which solar panels act and are enacted in specific ways and outline why I feel that a focus on everyday life provides a useful analytical plateau for an investigation of the power of solar panels.

2.3.1 Solar electricity as vibrant materiality

The notion of material agency is not new in human geography, but the manner in which different translations and applications are made is a matter of both difference and contestation (Tolia-Kelly 2013), which makes it useful to outline why and in what form the notion is useful for this thesis. Increasing interest in material or non-human agency forms part of the conceptual project of rethinking the great dualisms of nature and society, human and thing, local and global, what Latour has summarized as 'the modern constitution' (Latour 1993) into notions of what, following Sarah Whatmore's important contribution within human geography (2002) is often referred to as 'Hybrid geographies'. An important contribution to this field which is especially interesting for this thesis is Jane Bennett's work, which follows an interest in "thing power: the curious ability of inanimate things to animate, to act, to produce effects dramatic and subtle" (Bennett 2010 : 6, see also Bennett 2004) into a query of how to account for non human vitality or to understand better "the affect of technologies, winds, vegetables, minerals…and to theorize a kind of geoaffect or material vitality" (Bennett 2010: 61). The particular relationship between energy technologies and human beings in the majority of energy related research since the 1970s, and the following challenge to overcome this analytical and disciplinary division of them as outlined in the introduction, makes Jane Bennett's project an interesting one for this thesis: it offers alternative explanations for what 'unintended consequences' consist of. For an enquiry about solar electricity in particular it is relevant because Bennett goes beyond a curiosity towards human beings living with things and artefacts as has been the focus of the field of material culture studies (Miller 2005 see also Appadurai 1988), and questions actants which are not thing-like. Related to Bennett's work is Tim Ingold's recent call to 'take materials seriously' in which he argues that more effort should be put on the investigation of 'materials and their properties' rather than 'the materiality of objects' (Ingold 2011: 20). Doing this, he proposes, involves considering properties of materials to be not attributes but rather continually unfolding '*histories*' (Ingold 2011: 32). Read together (and allowing for a number of conceptual differences) they call for social theory to 'do a better job of recognizing the active participation of nonhuman *forces* in events (Bennett 2010 my emphasis), a call which is gaining ground also within human geography with recent enquiries of vital materials such as wastes and asbestos (Gregson and Crang 2010, Gregson, Watkins et al. 2010).

This move towards conceptualising *forces* such as weather (Ingold 2011) or electricity (Bennett 2005) provides an important starting point for an enquiry which deals with an unstable object which is both a technological device or a thing (a solar panel), and a force (solar electricity). Whilst separating these two can to a certain extent be done theoretically and analytically, empirically they flow together, co-exist and interact: in everyday use the agency of solar panels as thing and solar electricity as force cannot be straightforwardly separated. What this move then affords specifically an enquiry of renewable energy technologies and the powers they generate is to enable the question: what if the manner in which people use energy had more do with the physical properties of particular kinds of energy, than we often assume when we treat different kinds of power as equal or neutral? Timothy Mitchell's book on Carbon Democracy (2011) provides a compelling example of how the properties of oil have shaped modern democracies, but solar energy of course is a different power with different properties, which thus leads to different questions of their more-than-technical effects.

Questions of how technological devices and scientific facts come into being and act have been at the heart of the field of STS since it's beginning (Latour and Woolgar 1979, MacKenzie and Wajcman 1985, Latour 1987, Akrich 1994, Latour 1996, Law 2002). More recently, increased attention has been made to the manner in which these processes are also political (Jasanoff 2004, Latour and Weibel 2005, Asdal, Brenna et al. 2007, Callon, Burchell et al. 2011), or how "Objects…bind all of us together in ways that map out a public space profoundly different from what is usually recognized under the label of 'political" (Latour and Weibel 2005 : 15).

This increased attention to connections between techno science, democracy and public life has resulted in recent efforts to begin sketching out a "materialist theory of politics" (Braun and Whatmore 2010), by considering together insights from Science and Technology Studies and insights from political theory. Notions of 'material politics' have a history within STS, which it is relevant to consider here. The framing which this thesis considers most relevant for an investigation of solar panels at work in daily life has been described by John Law and Annemarie Mol as: "a material ordering of the world in a way that contrasts this with other and equally possible alternative modes of ordering" (Law and Mol 2008). This makes the politics in this thesis primarily "ontological politics" (Mol 2002) or heterogeneous and often contradictory mundane everyday practices which shape possible worlds without necessarily being involved in open controversy, debate or discussion. Ontological politics, Mol suggests "have to do with the way in which problems are framed, bodies are shaped, and lives are pushed and pulled into one shape or another" (Mol 2002: viii). Enrolling the notion of ontological politics in this thesis is to suggest that distributed agencies involved in the practicalities, affordances and difficulties of electricity-in-use in domestic households are seen not just as reacting to particular powers, but also performing and generating them.

Solar panels in such mundane everyday practices however do not exist in spaces of only one kind of politics. Solar panels are also particular political interventions, they are the 'stuff' of politics (Braun and Whatmore 2010) and they become political in particular ways in particular situations (Barry 2013). Solar panels assemble a multiplicity of politics, which may co-exist or may come into conflict (Mol 2002). Importantly, they are not passive and stable objects of human politics, but actively involved in the doing of politics. This conceptualisation is not just a rethinking of how agencies of materials of various kinds and in various states are considered, but also a rethinking of 'politics', not least in opposition to the Habermasian model of deliberate democracy where speech is the only medium, and where participants must disentangle themselves from their everyday material practices in order to participate (Latour and Weibel 2005, Braun and Whatmore 2010). These multiple conceptualisations of politics provide useful explanatory tools, when devices such as solar panels do not have the 'social impact' it might have been anticipated they would, or when this impact is not coherent or equally distributed.

As efforts to extend the STS vocabulary in order to better understand the constitutive and political nature of material processes and the manner in which the matter of politics is "party to the assemblage of common worlds" (Braun and Whatmore 2010: xv), are increasingly making links to political theory, questions emerge which relate particularly to the concerns in this thesis: questions of how materials and techno-scientific objects contribute to collective actions and their transformations, and how technology forms part of the art of government (Braun and Whatmore 2010). Or in relation to solar panels, how these become enrolled in multiple political agendas and how they come to contribute to changes to relationships between people and energies? Importantly as the question of material politics has begun capturing the imagination of geographers, a curiosity as to how and notably *where* materials *become* political, has led to a call for accounts of the political *geography* of materials (Barry 2013).

This thesis will go on to explore the material politics of solar panels and solar electricity in domestic settings in Sri Lanka and the UK, as a curiosity towards what worlds they assemble or are implicated in building there. Following the insight that materials become political differently in different places, Barry contends that "material objects should not be thought of as stable ground on which the instabilities generated by disputes between human actors are played out; rather they should be understood as forming an integral element of evolving controversies" (Barry 2013: 12) This view on materiality as indeterminate or contingent is important not least in investigations of solar panels in everyday life as it allows for an enquiry of how solar panels do not only become object of different human intentionalities, controversies and politics, but how they play an active and situated role in shaping these intentionalities, controversies and politics themselves, and what kind of spatial variation there is to these processes.

With materiality and the particular properties of materials being not a priori attributes, 'stable' or 'unstable' in and of themselves, but rather becoming and un-becoming stable as they are performed in particular situated arrangements, the question of what solar panels have 'something to do with', how and when, becomes important. As particular material politics emerge around the agencies of solar panels and solar electricity, they assemble a particular socio-material power, a power in order to do (Verbeek 2005) something in particular, which is not an attribute of solar panels alone, but the force of a particular assemblage (Bennett 2005). The following section elaborates on the contingent achievement of particular powers as assemblages, and how these can be unpacked analytically.

2.3.2 Solar panels assemble

As outlined in the previous section, materiality does not mean constancy, but is another way of understanding the performance of the world as achieved by more than just people. Shifting focus, as Braun and Whatmore have suggested, from the stuff of politics to the *stuff* of politics (Braun and Whatmore 2010), does not provide a stable or somehow more tangible ground on which to situate enquiry, but is employed in order to investigate how certain networks and connections come together or not in a particular way. This makes it possible to notice and conceptualise uncertainties and ruptures, which come into being as a result of certain arrangements. Here lies the power in assemblage thinking for this thesis: it enables an investigation of solar panels in which they 'start out' as general or anticipated capacity to do work in a domestic home but become part of assemblages which have presence and location (Li 2014) and which order not only meaning, but also matter and power. The notion of assemblage is an important vehicle for approaching and ordering material worlds. In this section I elaborate on how concepts of assemblages help provide a helpful analytical approach to solar panels in different places. I then suggest that the notions of enactment and intra-action further provides a useful means of engaging with the processes through which contingent assemblages of solar-use are made or unmade.

Devices such as solar panels are rarely considered objects of interest to social scientist merely in their capacity as technological systems. When solar panels are interesting devices in this thesis it is not because they are made up of materials, which, put together in specific ways, make them capable of generating electricity. The interest in solar panels in this thesis lies not merely in how solar panels work as technologies, but in how and to what they make connections: what they assemble and what they (intentionally or unintentionally) enable and afford. In order to understand how they do that it is useful to imagine them as if they were in the middle of a map (Deleuze and Guattari 1987), connected to all manner of things, people and ideas assembled around them. Solar panels then become 'somewhere to start' (Law 2002).

The concept of assemblage has become increasingly used in social science enquiry. It has many conceptual lineages (Anderson and McFarlane 2011) and takes different forms in different uses. In the majority of the literature however assemblages can be traced back to Deleuze and Guattari's (1987) understanding of a "rhizomatic principle of connection". It is useful to go 'back' to Deleuze and Guattari not because they somehow hold 'the original' idea, but because there are some particularly appealing things about their description of assemblage for the investigation of solar electricity, which is their emphasis on movement and temporality as well as spatiality: "a rhizome *ceaselessly* establishes connections" (Deleuze and Guattari 1987 : 8). Solar panels may be usefully imagined as being in the middle of a map, but it is not a map where roads spread only in space, they spread also in time. Another useful notion to take from Deleuze and Guattari in relation to an analysis of solar panels and solar electricity, is that this movement or connectivity is multiple, and follows "a principle of asignifying rupture" which means that an assemblage can be broken in one place only to start up new and different connections elsewhere (Deleuze and Guattari 1987 : 10). Solar panels are good at this: in order to understand the manner in which solar panels in different uses establish, cut and re-establish connections, this is a useful metaphor. A very relevant example of this kind of assemblage is Jane Bennett's example of the electricity grid (Bennett 2005). For a vital materialist (as Bennett often refers to herself), the grid is not a machine or a tool or a network of pipes which can be easily represented on a map, but a volatile mix of heterogeneous actants, "coal, sweat, electromagnetic fields, computer programs, electron streams, profit margins, heat, lifestyles, nuclear fuel, plastic…to name just a few" with constant friction between parts (Bennett 2010 : 25). The friction is important, an assemblage such as the grid is not neatly arranged, available for a complete overview from a particular point, unless you make a very specific selection or cut into what is internal and what is external.

Within human geography the notion of assemblage is also gaining ground. McFarlane and Anderson (2011) have suggested that efforts of thinking with assemblage can be understood as a curiosity towards process and formation: "not simply as a concept, but as an ethos of engagement attuned to the *possibilities of socio-spatial formations to be otherwise* within constraints and historical trajectories" (McFarlane and Anderson 2011: 162 my emphasis). Assemblage thinking offers an alternative to the "billiard ball image of cause and effect… [and a] less linear sense of the possible" (McFarlane and Anderson 2011: 162), or to speak with solar panels: the manner in which solar panels are currently being employed, and the worlds that they are implicated in ordering, *could be otherwise.*

When worlds involving solar panels could be otherwise this has a lot to do with devices and materials being less 'stable ground' than often assumed as outlined in the previous section. It has been suggested therefore that "'materiality', just as 'context' and its cognate terms, needs to be understood as the contingent upshot of practices, rather than a bedrock reality to be illuminated by an ontological investigation" (Woolgar and Lezaun 2013 : 325). Another way of considering this is to say that things in assemblages carry with them an indeterminacy (Braun and Whatmore 2010), not in and of themselves (solar panels behave perfectly predictably in a test laboratory, as I shall return to in chapter 4), but within particular assemblages: "spatial relations that at once contribute to this charge of indeterminacy and shape what is actualized at any given moment" (Braun and Whatmore 2010 : xxii). In relation to solar panels, this *charge of indeterminacy* in particular relations carries a great deal of explanatory power. Because solar panels can be encouraged to perform perfectly predictably *in some places*, like test laboratories, return on investment calculations and MACC curves, the "slight surprise of action" (Latour in 'Pandora's Hope', with Bennett 2010 : 27) which happens as these devices operate in messier assemblages involving homes in the UK or Sri Lanka, become 'unintended consequences' which it becomes difficult to understand and develop "response-ability" (Haraway 2008) towards in the light of the notion of a stable technology. In this thesis solar panels are sometimes stable, sometimes not. They are successful at certain times in certain places, and they fail at other times in other places. This makes it interesting to consider their situated agencies following a comparative analytical approach which can provide insights into how both spatial and temporal variations come to shape what is actualized (Braun and Whatmore 2010, McFarlane and Robinson 2012, McFarlane, Desai et al. 2014).

The co-existence of multiple assemblages of solar power highlights a further quality of the concept of assemblage in relation to a material but also multiple object such as a solar panel: the concept of assemblage disrupts and de-centres the object within and across different assemblages. John Law has spoken of this issue of objects that then become 'more than one but less than many' using the vocabulary of "fractional coherence" (Law 2002). There is a fractional coherence between solar panels in different assemblages, which can make certain things visible. Law talks about the potential of on analytical process of

> "growing different stories alongside one another. Smaller narratives – a lot of smaller keys. Working in this way has a cost: we do indeed lose the possibility of an overall vision. But at the same time we also create something that was not there before: we create and make visible interferences between stories" (Law 2002 : 5)

I shall return to this issue in chapter three but what Law suggests here, seen in relation to solar panels, is an analytical aspiration for them to reveal in analysis, not themselves, but *interferences* (or ruptures, following Deleuze and Guattari (1987) between contingently achieved stabilities or 'stories': like solar panels that work and solar panels that do not. This fluidity which will become apparent as this thesis moves into its empirical chapters, which come to show how, as Woolgar and Lezaun have described it: "objects are brought into being, they are realized in the course of a certain practical activity, and when that happens, they crystallize, provisionally, a particular reality, they invoke the temporary action of a set of circumstances" (Woolgar and Lezaun 2013 : 323).

Solar panels then *are realized* and *crystalize* in different assemblages. And the interferences between the manner in which this happens in everyday life in the UK and in Sri Lanka, in laboratories, in Feed-in Tariff policies, and at the World Bank, are interesting to unpack. The following section suggests two concepts, which provide a useful means of doing this: the notion of intra-action and the notion of enactment.

2.3.3 Intra-action and enactment: achieving powerful assemblages

Considering solar panels as objects that are brought into being in assemblages is not how they are most often approached within engineering and policy communities as already outlined. This is difficult to think within a conceptual framing where devices are considered to be stable, predictable immutable mobiles. It is not simply an exercise in philosophy however, as Karen Barad (Barad 2007) has suggested in her efforts to conceptualise relationships between meaning and matter, something which it is interesting to bring in here. If the material efficiency of solar panels is to be seen as something which is not just achieved once and for all before solar panels are deemed mature enough to be 'rolled out' to households across the globe, but rather as contingent and situated, it is useful to consider not just what is assembled but also how things in assemblages hang together.

For Karen Barad, objects and subjects do not precede their connections or relations in an assemblage, but rather emerge through their particular *intra-action* (Barad 2007). Contrary to assemblages following Deleuze and Guattari (1987) which consist of ever changing movements and connections between actants, Barad's 'assemblages', or as she would prefer "phenomena", are the condition of possibility for objects and subjects. (Barad 2007 : 140). Drawing on insights from theoretical physics, particularly the work of Niels Bohr, Barad considers these phenomena "material-discursive": "phenomena are the ontological inseparability/entanglement of intra-acting "agencies". That is, phenomena are ontologically primitive relations – without pre-existing relata" (Barad 2007 : 139).

There are a number of differences between the manner in which Deleuze and Guattari understands assemblages and the way phenomena are understood by Barad. What Barad's phenomena add to assemblage-thinking particularly in the context of solar panels, I think is twofold: Firstly she enables an enquiry of solar panels in which the spatial variability of their intra-action is integral to their local workings. If objects and subjects do not precede their intra-action then devices such as solar panels cannot be considered neutral and passive devices, which can be handled, in different assemblages understood as contexts. Instead their properties and propensities (how, where and when they generate how much electricity and what kind of current) emerge in everyday life: "agential realism rejects the notion of a correspondence relation between words and things and offers instead a *causal explanation* of how discursive practices are related to material phenomena" (Barad 2007: 44, my emphasis). Powers with Barad are not merely affordances, which can be freely interpreted and used through discourse.

Secondly Barad attends to the politics/ethics of mattering, by conceptualising matter and meaning as co-emergent, "values are integral to the nature of knowing and being" (Barad 2007 : 37) . Phenomena and the apparatuses which produce them, are 'material-discursive', they produce *determinate* materialities and meanings, excluding the production of others. Barad draws on Foucauldian understandings of discourse and power and wants her agential realism to contribute to a more materialist understanding of power (Barad 2007 : 35). But understanding is not enough. As matter and meaning become inseparable, attending to the political and ethical responsibilities of science is no longer a choice but a necessity. Barad then makes the research situation, the 'cuts' that the researcher makes, part of the apparatus, the researcher is always present: any act of observation and knowledge-making is always already a material-discursive act and therefore political and ethical. Science (the kind that makes devices as well as the kind that evaluates their use) is situated as part of any given phenomena: uncertainty and indeterminacy are very different things (Barad 2007 : 115). Barad here makes important links to Donna Haraway's calls for 'response-ability' (Haraway 2008) and Jane Bennett's calls for alternatives to 'politics of blame' (Bennett 2010), a challenge which has also been raised within geography: "The trick is not to stand outside the assemblage and trace its contours and composition, but to ask how we are already implicated within it and ask if we might (want to) use that involvement in politically productive ways" (Greenhough 2011: 137, see also McFarlane and Anderson 2011). These comments touch on an old criticism in relation to Actor Network Theory, which is relevant also in relation to assemblage thinking: the problem of a style of analysis that can theoretically go on endlessly, and the necessity of attending to questions of the 'cutting [of] the network' (Strathern 1996). Although Barad's phenomena do not limit as such the 'ceaseless connectivity' of assemblages, they make it impossible for the observer to position herself outside them. For Barad, distinctions between ontology and epistemology become cut differently, and although it is a long and somewhat dense argument, the extent of her connection between meaning and matter is useful to explore:

> "The separation of epistemology from ontology is a reverberation of a metaphysics that assumes an inherent difference between human and nonhuman, subject and object, mind and body, matter and discourse. Onto-

> epistem-ology – the study of practices of knowing in being – is probably a better way to think about the kind of understandings that we need to come to terms with how specific intra-actions matter. Or, for that matter, we need something like an ethico-onto-epistem-ology – an appreciation of the intertwining of ethics, knowing, and being – since intra-action matters, since the possibilities for what the world may become… the becoming of the world is a deeply ethical matter" (Barad 2007: 185)

Or put more simply, and in relation to solar panels: coming to know solar panels involves setting up an apparatus which makes specific cuts in the world, they are always already political and ethical. This latter point is particularly important to discuss in relation to methodological considerations and I shall therefore return to this in the following chapter.

Before this however a question arises of how to proceed with an investigation of intra-action within assemblages: how to enquire about them or how to see them. This is again a question which is not easily situated between categories of concepts and methods and which I return to in the following chapter. It is however necessary to briefly introduce it here. In this thesis I employ the notion of enactment often associated with Annemarie Mol and her praxiographic enquiry of multiple enactments of the disease atherosclerosis (Mol 2002). What Annemarie Mol has shown with the notion of enactment is that when different groups of people within the Dutch Medical System such as GPs, vascular surgeons, pathologists and patients have different understandings of what atherosclerosis is, these different understandings are not merely different interpretations of the same object, they are enactments with different assemblages of objects. Enactment I feel is a useful concept in order to emphasize the contingent and distributed achievement of assemblages of solar electricity: the notion that they are not merely out-there, but that they are indeed being enacted, assembled and brought into being in time as well as in space. Enactment locates knowledge in events, buildings, procedures, devices and so on, but importantly in them being intra-acted with:

> "It is possible to refrain from understanding objects as the central point of focus of different people's perspectives. It is possible to understand them instead as things manipulated in practices. If we do this – if instead of bracketing the practices in which objects are handled we foreground them – this has far-reaching effects. Reality multiplies" (Mol 2002: 4)

Enactment then is not an alternative explanatory framework to assemblages, but an event through which assemblages are made to happen or made visible – or where everyday processes of intra-action and becoming can be observed. Understanding solar panels as 'things manipulated in practices' or solar electricity as a force being intra-acted (with) emphasizes a particular stance in relation to assemblages in this thesis: an interest primarily in how assembl*ing* is done, and how specific assemblages – and with them specific "ontologies, are being brought into being, sustained, or allowed to wither away in common, day-to-day, socio-material practices" (Mol 2002: 6).

Moving forward then the notions of material agency, assemblage, intra-action and enactment have paved the way for an enquiry of solar panels as devices being 'manipulated in practices'. The following section elaborates on the potential analytical merits of considering what devices in everyday practices and assemblages are capable of.

2.3.4 A domestic power: The home as material participation

I have argued that understanding how multiple material politics come together in different settings can help explain how a particular material force emerges. In this section I focus on 'the home' and argue that an enquiry of the material politics of solar panels in domestic houses opens up two things: firstly that something happens to 'the home' when solar panels become part of it, and secondly that the meaning-matter of solar panels in domestic houses shapes a particular kind of energy.

The notion of everyday life is an important element in social research particularly within social anthropology and human geography and has also informed a great deal of the research done on energy consumption as outlined in the introduction. A relevant example for this thesis comes from the field of urban studies, specifically in relation to sanitation, where it has been argued that "attention to the everyday reveals the practices, geographies, rhythms, perceptions, experiences, politics, and power relations that reproduce, disrupt, and remove informal urban sanitation as they occur within the neighbourhood" (McFarlane, Desai et al. 2014: 990). Attending to everyday practices of doing sanitation this research has highlighted how informal sanitation works as a contingent assemblage: how sanitation is produced, maintained, changed and contested (or enacted) on a daily basis and in response to many different forms of agency. Interesting parallels can be drawn between sanitation and power consumption as these are both examples of everyday activities and infrastructures whose everyday maintenance and repair play a very important part of the functioning of societies, but which are often overlooked unless they break down or fail (Graham and Thrift 2007). The everyday then provides not a firm setting, but a fluid and heterogeneous achievement, which provides an analytical plateau where all manner of agencies intra-act. For this thesis the analytical plateau of the home can provide information about what solar panels assemble, or what they have 'something to do with': what it requires for them to work and what the consequences or their specific workings are. It draws inspiration in particular from research which has focused on everyday practices of 'living with things' (Gregson 2007), which has shown how consumer goods are continually becoming through the course of their lives in the home (Gregson, Metcalfe et al. 2009).

I have outlined already how the expectation of a causal relationship between attitudes and behaviours in relation to energy usage has been criticized in social science energy research, but remains a powerful notion in energy policy in the UK (Owens and Driffill 2008, Shove 2010). This is also a trope in Noortje Marres work on 'material participation', which provides important inspiration for this thesis (Marres 2012). Noortje Marres is concerned with what she sees as a growing popularity of a more material strategy towards achieving the goal of behaviour change. She suggests that this shift from a focus on 'literacy' (people's knowledge about the environment) to 'action and impact' (what people can do in everyday life), is a shift which partly replaces the 'informational citizen' with another figure: the 'material public' (Marres 2012: 5). Material participation, Marres contends, consists of an attempt to locate public engagement with issues such as climate change in everyday material practice, rather than in the minds of human beings. Importantly however 'the public' here, is a heterogeneous one: it consists not of human beings alone, but of a whole range of actors, many of who are material objects. Approaching solar panels through this kind of lens puts them in an empirical category with a number of other 'green' devices such as energy saving light bulbs, water saving showerheads and augmented teapots, which are increasingly being invested with capacity to help make environmental engagement 'doable' and 'easy' (Marres 2011, see also Hawkins 2006 and Hobson 2006). This follows an assumption that people are more likely to engage in environmentally friendly behaviour if it can be done with as little effort as possible (Marres 2011). A growing curiosity about the manner in which these kinds of devices become enrolled in the making of a particular kind of environmental citizen (Hobson 2013), a process sometimes referred to as 'responsibilization' or the individualization of responsibility for the environment (Hinchliffe 1996, Maniates 2001), through which responsibility for environmental governance is shifted and distributed from central governments onto particularly framed individual citizens, and particularly important for this thesis, onto technological devices such as solar panels. It is also the latter point which interests Marres who sees this use of devices to "do the hard work", as constituting a material redistribution of the problem of environmental participation itself in that it shifts responsibilities and capacities onto heterogeneous settings, away from human beings (Marres 2010). In the design and deployment of domestic solar systems there is a considerable amount of responsibility distributed to non-human devices and technologies. For Marres this prompts the need for a device-centred focus. In the context of desired behaviour change, the question of a device's ability to influence human beings becomes central: specifically the question of what might enable a technology or a particular device to mobilise – or not – a particular socio-technical change.

The question of how devices may or may not come to assert political powers and form part of the art of government (Braun and Whatmore 2010), extends beyond an enquiry into the device itself: it opens questions of how differences between categories of 'politics' and 'everyday life' are commonly drawn and how relations between public involvement and everyday material practices are understood (Marres 2009). 'Participation made easy' through the deployment of devices such as solar panels, translates the home into a privileged site of political experimentation and participation as well as a site for responsibility for the environment (Marres and Lezaun 2011). Marres' analyses of the eco show home as a material instrument of engagement in what she calls 'a particular experimental form of material politics' (Marres 2012 : 107), is particularly interesting in relation to this thesis because of what happens to the analytical position of 'the home'. In this account, 'the home' moves from a position in conceptual framings such as consumption theories where it is a prime location for consumption of energy and a place where broader practices of energy use can therefore be illustrated and investigated, to a prime position of experimental material participation in environmental policy. What happens in the home, not least what devices such as solar panels do or encourage others (humans or non-humans) to do becomes political, as everyday activities such as putting on the dishwasher are re-cast as ways of action on the environment.

Although Marres' account of the position of the home as bound to issues of the environment is a powerful and useful explanatory framework in relation to solar panels in the UK, it is developed in a particular geo-political context and is as she herself points out an *empirical* phenomenon (Marres 2012: 5). It does not therefore speak as convincingly of 'the home' in places like Sri Lanka. This provides an interesting conceptual challenge. As already introduced in the first chapter of this thesis and in relation to the literatures specific to solar panels in the UK and in Sri Lanka, solar panels in Sri Lanka are different political interventions than they are in the UK, different 'technologies in order to' (Verbeek 2005), which makes them a different empirical phenomenon. Rather than devices and forces participating in politics of environmental governance, in Sri Lanka solar panels become implicated in politics of international development. Material participation then must ask not merely about the manner in which the material participates, but what it participates in. Extending the notion of material participation to households in Sri Lanka does two things: it unsettles the question of what it means to participate and in what, and it reminds us of the notion that technologies are not neutral affordances but political both in their intentionality (in what they are there to achieve politically) and in their material capacity (what they are able to do as situated powers). As this thesis moves into its empirical chapters it will illustrate how the relationship between discursive and material powers of solar panels create both friction and ambivalence.

2.4 Conclusion

In this chapter I have argued that a curiosity about everyday enactments of solar panels in domestic homes can shed light on how they become particular situated forces or kinds of energy. I have suggested that situations of multiple material politics shape and are shaped by the manner in which solar panels are made to matter in domestic everyday lives and that the outcome of this are not only modes of ordering but also particular material capacities with consequences for the wider energy system and carbon emissions.

I have suggested that existing literatures which have focused on domestic solar either in the context of the UK or in Sri Lanka have predominantly considered issues around diffusion and human interpretation of the technology and that they would benefit from increased attention to everyday enactments of living with solar, in particular further attention to the indeterminacy of solar panels in particular assemblages.

I have argued that domestic solar electricity should be investigated not as a neutral resource, but as an actant, which is actively involved in the situated achievement of particular assemblages of everyday powers. This I believe can offer a useful account of solar technology and electricity in use and the entanglements and ambiguities arising from particular enactments. It offers in particular an account in which the properties and propensities of particular powers are seen as actively contributing to material-discursive orderings of the world, which could be different.

This chapter has proposed that a diffractive or comparative analysis of everyday enactments of solar power in two different assemblages in the UK and Sri Lanka offers insights into how situated solar powers are achieved and made to matter in different ways and how the particularities of these powers relate to the different socio-political intentions and expectations which support their presence in domestic households.

The following chapter outlines how this thesis has translated these insights into a methodology aimed at bringing out interferences between and within accounts of how solar panels as indeterminate devices and the vibrant materiality of solar electricity become enacted and lived with in homes in the UK and Sri Lanka.

3 Ethnographies of solar assemblages

> "… apparatuses are specific material reconfigurings of the world that do not merely emerge in time but iteratively reconfigure space-time matter as part of the ongoing dynamism of becoming". (Barad 2007: 142)

3.1 Introduction

Having introduced the notion of energy as problematic in Chapter 2, the intention of this methods chapter and the thesis more broadly, is to disturb that notion. Because energy is almost always considered problematic in a particular way at the point where social scientists get involved with it (to consider problematic energy behaviours or environmental impacts for example), methodological considerations often relate to the nature of the perceived problem. They are often concerned with how to best investigate and make sense of human behaviour or socio-technical infrastructures, rather than how to best illuminate the multiple and distributed agencies of energy itself. As I have already suggested in Chapter 2, social science has perhaps been more interested in the social effects of energy as resource, and whether energy is visible to consumers (Hargreaves, Nye et al. 2010), rather than whether energy or indeed different kinds of energy are visible and knowable to social scientists. In this chapter and in the thesis more broadly, I wish to be more curious about energy. I wish to develop a greater curiosity about what it does *as energy*, as a capacity to do work, which puts this thesis perhaps at the more exploratory end of the spectrum: it wants to find a way to explore solar photovoltaics as everyday agency.

This does not mean that I do not agree that energy is indeed a problematic subject. Rather it means that instead of attempting to solve this problem, I wish to create and look at it through a different lens, or a different "material arrangement through which particular concepts are given definition, to the exclusion of others, and though which particular phenomena with particular determinate physical properties are produced" (Barad 2007: 142). The particular phenomena which I am curious about creating is one in which energy is not always already problematic in a particular way (as a contested resource or in relation for example to climate change or international development), but becomes both powerful and problematic in particular assemblages. Believing with Barad, (see also Hacking 1983) as the quote at the beginning of this chapter suggests, that analytical lenses, or as she prefers "apparatuses", are not context-independent or neutral observing instruments, but productive and part of the phenomena they observe, I seek in this chapter to account for the work involved in creating the particular lens which has been put to work in this thesis.

Approaching solar energy in a manner where it is the solar energy itself, rather than its effects or the problems it creates or tries to solve, which is of concern, requires an attempt to disentangle it from its analytical position as a problem in need of solving. In order for me to explore energy as if it was not always already problematic requires a position where I can *allow* it, appreciate it even, not be in a hurry to make judgments about whether it is good or bad, but much more humbly try to understand what it does, how it comes to do what it does.

In this chapter I suggest a route for doing this. Section 3.2 considers how notions of diffraction can be put to work in order to consider interferences between ethnographic sites. Section 3.3 then introduces the methodological tradition of Ethnography and accounts for the manner in which it has influenced both the way in which the research was carried out and the way in which it was made sense of through the process of writing about it . Section 3.4 introduces the empirical sites in the thesis and considers the manner in which these were assembled and came to relate to each other. Section 3.5 is concerned with the particularities of doing ethnography throughout this thesis and considers in subsection the trouble with data (section 3.5.1), ethnography as experiment (section 3.5.2) practices of adjustment (section 3.5.3) and finally processes of collaboration (section 3.5.4). Section 3.6 offers concluding comments on the particularities of ethnographies of power.

3.2 Diffraction as method

In the literature review I suggested that a diffractive reading of enactments of solar panels in Sri Lanka and the UK provided a useful means of considering the emergence of different material dynamics and politics, not merely between the two empirical locations, but also within them. The word comparison is troubled by having been used in a manner which envisages a world which it is a little bit too easy to capture (Tsing 2014). Sri Lanka and the UK are not straightforward comparable entities as already stated. There is however as mentioned in the literature review growing effort particularly within Geography to develop comparative imaginations beyond this tradition of comparing entities, which seeks in particular to find ways of attending to analytical connections between what has often been termed developed and underdeveloped places (McFarlane 2006, McFarlane and Robinson 2012). This thesis suggests that a useful manner of developing different modes of comparison can come from engaging with the work of Karen Barad, particularly her notion of diffractive readings (Barad 2007) as well as Marilyn Strathern's reiterative comparisons (Strathern 2004, Street and Copeman 2014).

Marilyn Strathern has used comparative readings of different cultural orderings in a manner where it is less the difference between one geographical or cultural landscape and another, but rather the differences within these landscapes that matter. Comparison for her has been a means of reification: "an interruption, a refusal of connection to show the gaps through which we can rethink our categories" (Tsing 2014). It is a way of questioning our own knowledge making. It does not aim to create order (or to order entities for comparison), but rather to allow for a disorientation and an exposure of both the chosen objects and the tools used to choose and frame them. The incompatibility of the units is what illuminates this. As this thesis also works with "units" that are neither straightforwardly understood as entities nor comparable in a traditional sense, Strathern is an important source of methodological inspiration for this thesis. I find it useful however to use Karen Barad's notion of diffraction as a supplement to the notion of comparison. Reading worlds diffractively progresses not by establishing categories or orderings with which to put two places into relationship with each other, but rather like rings in water by attending to analytical consequences of many contingent connections. Or put more empirically, it makes it possible to put insights you have acquired by observing particular connections in one place to work in another, like knowledge about how solar panels are lived with in differently shaped daily lives. Doing this can then help illuminate not just how solar panels in these two different places come to have different powers, but also how the scholarly categories we employ to investigate them disclose particular worlds in particular places. As the empirical assemblages of solar in Sri Lanka and the UK and the narratives of different literatures relating to these places become mixed up, they are made visible and contestable. Concepts from the energy research field do not seem to fit quite so straightforwardly with the situations and assemblages in rural Sri Lanka and vice versa. It would not be unusual to find a way out of this by separating the two, aligning conceptualisations and places to arrive at smoother analytical outcomes, tell more coherent stories, and there might be good reasons for doing this at particular stages and according to different research questions. But this thesis does not seek to show that solar panels are assembled differently in Sri Lanka and the United Kingdom. This goes without saying. It seeks instead to investigate the analytical potential in reading these assemblages through one another. Allowing the discomfort of misaligned conceptual vocabularies and geographical locations to stand for a while (Tsing 2014), is a means of doing so.

Reading the two assemblages diffractively however, does not do away with the need to come to know and make sense of them as connected but still analytically coherent entities. In the following section I introduce the methodological approaches that have helped me consider the manner in which specific worlds come together around situated solar panels, in Sri Lanka as well as in the UK.

3.3 Ethnography as curiosity

This thesis is based on ethnographic fieldwork . It considers ethnography to be not a single, descriptive method to apply to a research question, but rather a particular curiosity which shapes the entire process; which begins already at the time of making up initial research questions and goes on through the process that eventually produces a written product. Ethnography seeks to make sense of the world by means of following empirical connections or trails in more or less experimental manners (Pryke, Rose et al. 2003, Ingold 2011). They proceed by following connections as they manifest themselves in empirical enquiry, driven by a curiosity about how worlds are assembled, whether this is understood around classic studies of kinship structures or networks of technological innovation. Importantly ethnographies are ways of ordering the world from an empirical place in it. Because ethnography does proceed from a particular empirical place in the world and is shaped by choices made in this place, ethnographic enquiry necessarily involves a curiosity about the knowledge practices where these choices are made. Clear lines between ontological and epistemological concerns are frequently not easily drawn: questions of how knowledge is achieved are not separate from the knowledges themselves (Barad 2007). A key ingredient in this methodological stance relates to what has been nicely phrased by Isabelle Stengers as "the joy of not knowing" (Stengers 1997). Sarah Whatmore has summarised Stengers' thoughts on the scientific craft, suggesting that*:*

> "It is a joy less of knowing than of not knowing that she argues is a defining feature of scientific knowledge practices, but one that invariably gets written out of scientific literature and education…by the unexpected being retrospectively accounted for as the consequence of an ultimately rational method or correct theory…" (Whatmore 2003: 98)

Although this element of not knowing is frequently omitted from research publications, it is something, which underlies in particular ethnographic research processes, where the notion of the joy of not knowing becomes an important link to the tradition of ethnographic enquiry where the element of the unexpected is a cornerstone. The link becomes very clear in Marilyn Strathern's summary of the *craft* of ethnography as a way of investigating the not yet known:

> "the deliberate attempt to generate more data than the investigator is aware of at the time of collection. Anthropologists deploy open-ended, non-linear methods of data collection which they call ethnography… rather than devising research protocols that will purify the data in advance of analysis, the anthropologist embarks on a participatory exercise which yields materials for which analytical protocols are often devised after the fact... the ethnographer

> may work by indirection, creating tangents from which the principal subject can be observed…But what is a tangent at one stage may become central at next" (Strathern 2004 : 5).

What particularly Marilyn Strathern is associated with but also anthropological research more broadly is a particular interest in enabling empirical information to challenge existing concepts and theories, making ethnographic enquiry not merely a means to obtaining information about particular places, but a means to putting existing conceptual frameworks at risk.

Although ethnography is not a descriptive method but rather an approach, which is shaped by, what it is an ethnography of, when referred to the broad church of ethnographic literature particularly within the tradition of anthropology, ethnography has traditionally focused on the manner in which human beings order meaningful worlds. Objects have always been a part of ethnographic enquiry, however there has been a tendency for these objects to be exactly that – objects which were endowed with different kinds cultural meaning and politics. This position of objects has been criticized for not appreciating the manner in which non-human agency plays a part in ordering worlds (Latour 1993, Ingold 2011, Tsing 2014), a criticism which is very important to an ethnography which has solar panels and the more-than human assemblages they operate within as its focus. An important requirement for this ethnography is then to include the agency and vibrancy of stuff; of solar panels, of light bulbs, meters, flows of electrons and many other things which participate in the ongoing shaping of the particular assemblages of solar in the research, not merely because human beings are found to think of and handle them in particular ways, but because they have their own agencies.

At the end of this chapter I aim to have translated solar energy from something problematic to something unknown. I like to think of this approach as a curious one, one in which coherent analytical categorisations are *put at risk* by empirical investigation (Isabelle Stengers with Whatmore 2003:97), rather than what directs it. I try in other words to write as I walked, or as I carried out the research in a manner where the messiness and joy of not knowing is not, as described above written out of the account, but present as something which has both shaped it and generated it.

Writing this I borrow from the tradition of auto-ethnography (Goodall 2008, Pink and Mackley 2012), not in the sense that I write ethnographically about my own life, but in the sense that I situate myself in the text and I use the process of writing as a means of analysis Particularly in this chapter I make myself part of the narrative to illustrate my role as both researcher and author. Doing this, I realize, may cause some confusion, which I need to try and limit beforehand. This text was not written chronologically, but includes a number of sections, which were written at different times in the research process, when particular notions or insights crystallized for me. In an attempt to not edit this process out I have edited these bits very little. I signpost them by an indentation followed by **(research diary, date)** and I come out of them again by means of a section break. In this manner I try to contain in the text the process of doing ethnography as one that is distributed temporally and spatially and in which notions of separate efforts of investigating, analysing and writing up make little sense. The following section firstly focuses on the different sites, which have shaped this thesis.

3.4 Fields and other important places

This section introduces the locations in the UK and in Sri Lanka where the research for this thesis was carried out. It consists of three sub-sections: Section 3.4.1 introduces Sheffield Solar Farm and the circumstances under which this PhD began. Although this site is not a field-site in line with the two ethnographic field-sites of the thesis, it is a site, which has greatly influenced both the methodological approaches and the findings of this thesis, which makes it important to introduce here. Following this subsections 3.4.2 and 3.4.3 introduce field sites in the UK and Sri Lanka respectively and outlines how ethnographic practices were arranged and adjusted in these sites.

3.4.1 Sheffield Solar Farm

Any ordering of empirical material involves a certain degree of entanglements and overflows (Callon and Rabeharisoa 2004). So does a diffractive reading; rings in water do not touch only two shores. There are two geographical field sites involved in this research. Or rather there were, until I started writing. In this thesis there was always solar panels in Sri Lanka and solar panels in the north of England. But as the process of writing the thesis began it became increasingly clear that I had an extra field, which was unaccounted for. Including it in this section creates a certain amount of havoc with the spatial and temporal delineations of ethnographies or field-sites in the thesis. The question of what makes a field-site a field site and what can be considered internal and external to it are complex and in something of a flux in much recent literature on ethnography (O'Dell and Willim 2011, Wilk 2011). So although I would not call it a field site as such, its importance in shaping the thinking and the investigation of this thesis is so great that it has to be included nevertheless.

I am talking here about Sheffield University. Specifically the Physics Department at Sheffield University, and in particular the part of it that calls itself Sheffield Solar. This was where I spent a very large part of the first year of my PhD, and the circumstances under which this PhD started, have played a large role in shaping the way I have approached it both theoretically and methodologically. Originally part of the PV Futures PhD Network at Sheffield University, this PhD started its life as one of 3 interdisciplinary PhDs in a new network at Sheffield University, which had the Sheffield Solar Farm at the Department of Physics and Astronomy as its focal point. It initially had Professor of Physics and Astronomy, David Lidzey, as a secondary supervisor, and involved attending a number of physics and engineering modules on various aspects of PV science and technology. For someone with only a loose grip on particle physics and how semiconductors work, the learning curve in the first few months was practically vertical, but I did learn how solar cells work and I did gain a lot of information which enabled me to approach much more technical aspects of photovoltaics than I could before. I learned about properties of coal and gas fired power as opposed to photovoltaic power, about energy transmission, voltage fluctuations: the constant work which goes into enabling the National Grid to provide power in the seamless and invisible way it does (Graham and Thrift 2007). Importantly from a methodological point of view, Sheffield Solar was a very important stepping stone for learning to be curious about non-human agency which is not merely interesting because human beings attach certain kinds of meaning to it, but because it has agency; power, velocity, capacity, propensity, all of which can be enquired about in its own right. This kind of curiosity about 'how stuff works' on the one hand, and knowledge about how it is being investigated and questioned in techno-science, became a particular driving force in the way I came to arrange my ethnography.

The following excerpt from my research diary is from the time when my understanding of the agency of PV began to crystallize:

(Research diary, 7/11 2010): its unknown waters for both of us. David Lidzey, Professor of Physics and Astronomy, and expert on PV, has supervised a number of PhD students already. But they were Physics graduates. I'm from Human Geography, with a background in social anthropology even. I know very little about physics. I hope he will not question me about the first law of thermodynamics, which I have just had to Google because of a conversation with Adam, the physics PhD student, before the meeting. This is very basic stuff for a physicist. Where are we to start? *"David, what is energy?"* seems as good a place as any. Energy is one of those concepts that you can talk about for hours without really agreeing on its definition. I had spent a few weeks reading social science literature about energy, about how it is invisible, how people use too much of it in some places or can't afford it in other places. David's answer was therefore surprising to me: *"Well, energy is dangerous, people must be kept from direct access to it"*. If you only read social scientific literature about end-of-pipe energy consumption, it is easy to forget this. But here, in the physics department at Sheffield University, energy is power, it's a lot of power, it can kill you. David continued: *"Energy is capacity to do work"*. It does stuff. It may be invisible in the social science energy literature, but here, in David's office that doesn't really matter, it does work, it has agency, it makes a difference. I'm not sure why this is a surprise to me. I think somehow I thought physicists could see electricity better than social scientists. They can't, they are just not that concerned about this. They know it is there, because they can see what it does. *"You can't use it up, it just transforms into a different kind of energy as it is diffused"*. Energy is not the same thing as electricity either; the energy, which lights up David's office, is electricity only for a while, before it was perhaps coal, now it is light. The man

> whom I somehow suspected might help me see electricity, I think has just showed me that I don't need to see it to believe it. *'You can't really see the wind either, can you?'* says David jokingly. So there it is, energy, completely present and powerful in its agentic capacity. Visibility is a red herring! Energy, be it solar electricity or a different kind, is power, and it does stuff. This is the kind of energy my thesis will be about.

Spending the first year of my PhD at the Physics dealing with new information much in the same way I dealt with fieldwork would come to have consequences not least for the manner in which I came to think of different kinds of information or "data", assembled in "fields" or other places, as I return to in section 3.5.1. Although I spent a lot of time in my first year reading social science literatures, I also observed, I interviewed my new colleagues about cosmology and semi-conductors and The National Grid. I participated and tried to make sense of lab experiments with green lasers and lectures about electrons and holes. I also tried, slowly by a method of trial and error, to distance myself from the expectations of me as a *people expert*. I was surprised and amazed at the manner in which I as a social scientist was expected to participate in solving the problem of human beings doing the wrong thing. And it took a lot of time and much conversation before reaching a state where I was able to communicate – based on my growing understanding both of the "culture of physics" and my own disciplinary position why that role of people expert was so disagreeable to me (Henning 2005), and why the notion of people doing the wrong thing was so problematic.

So the first year of this PhD also taught me a lot about scholarly assumptions both in science and social science, in particular how the different ways in which the two engage with issues of overflow and uncertainty. The result was neither one of disciplinary confusion nor one of disciplinary certainty (or arrogance), but one of curious engagement. As my interdisciplinary encounters challenged the way I approached both energies, concepts and people, causing both confusion and clarity as I went along it became increasingly clear to me that the way I was negotiating this was as an ethnographer. Working with a fluid position in disciplinary categories such as 'Geographer', 'Energy researcher', 'Social scientist' and 'Social Anthropologist' as I went along to make myself a meaningful part of different contexts, what became increasingly solid was my scholarly identity as an Ethnographer. My conceptualisations of energy were getting increasingly interdisciplinary, moving me into new literatures and different academic contexts, but the manner in which this process of assembling theoretical and empirical information was carried out countered this fluidity by solidifying certain assumptions about how to approach the world methodologically.

The process of moving back and forth between different and sometimes opposing disciplinary understandings of energy revealed different conceptualisations and multiple energies between my non-social-science colleagues and myself. This was something which was not merely a rhetorical question as it turned out we would at times be talking about different material phenomena. Whilst I as a social scientist would use the term technology very broadly, often including several devices, talking for example about domestic PV technology as including monitors, wires between inverter and fuse box etc., this was a more generous use of the word than the tighter and more precise definition for example engineers were used to, so they would be confused about what exactly I was talking about, 'PV technology' or 'electricity monitoring technology' or just 'electricity'? My definition of a 'domestic technology' made very little sense to them initially as the question of where a technology is, whether in the home or in the lab is considered external and somewhat irrelevant to their understanding of it (Mol and Law 2001). Whilst we developed better understanding and acceptance of each other's inclusions and exclusions in the definition of things, I was still confronted with the often vague and imprecise vocabulary of the social science energy discourse. Being not only in frequent interdisciplinary conversation which necessitated clarity but also conceptually enrolled in a literature in which materiality matters, 'cleaning up' my vocabulary became an important part of my methodological approach to energy flows. This does not result in energies being any less multiple, quite the contrary, it makes it clearer how talking about energy in the singular covers over a number of different material forces and phenomena. I learned to use the word 'energy' to talk about a capacity to do work, a capacity to do a particular amount of work, like a load of washing, which can be measured quantitatively in kWh, or a general capacity to do work, like the total energy use (electric *and* thermal) of a household. And I began to use the word 'electricity' to talk about the flow of a particular kind of energy, its power. I noticed how some other social science enquiries of energy consumption didn't distinguish much between energy and power, or between kW and kWh, and noticed how talking about flows of electricity makes it indeed difficult talk about one or the other: the quite literally flow together. The difference between power and energy is nevertheless a difference, which has important consequences when you are trying to understand the capacity of PV panels, and the way they relate materially to the notion of energy consumption. Appreciating the difference between the two also enables you to spot problems like the assumption that "access to electricity" might have an impact on the amount of time people in rural Sri Lanka spend collecting fuel wood for cooking. I shall return to this issue in Chapter 4.

Looking back on that first rather seminal year of the PhD these were the two things, which came to make a big difference for me: firstly that solar electricity does stuff. The important question (to me) is not if human beings can see it or not, but what it can do. Secondly it is not either meaning or matter but always already both. The power of solar electricity must be understood and investigated as both meaning and matter and methodologically this means adjustments must be made. Becoming much more familiar with the knowledge practices through which energy and electricity are made sense of in Physics, thus altered the way I framed my subject on the one hand, but also challenged my methodological thinking. At the end of this chapter, I consider the notion of experimentality as a means of understanding ethnographic and analytical processes, which is something, which is directly related to my experiences of doing experiments in the physics department at Sheffield University. Before moving on to that it is important now to introduce the empirical locations which formed part of this research. In the following two sections I describe the two field-sites in the UK and in Sri Lanka and explain how they were achieved methodologically.

3.4.2 Solar Panels in the UK.

Figure 3-1: Matt's house and garden- a typical PV household installation in the UK

In this thesis I draw on ethnographic material which I achieved from repeat visits to 15 households during the first 1-2 years after they purchased and installed PV systems on their rooftops in the north of England (Leeds and Sheffield). With the exception of two households whom I only visited once (one household moved abroad after the first visit whilst another asked to be excluded due to severe illness), I visited each household twice a year apart, and carried out unstructured interviews (of between 1 and 2,5 hours each) which all involved going out to look at panels, looking at inverters, various monitoring devices and also looking at calculations, spread sheets and graphs people had made. I used a digital recorder to record interviews and took pictures on my smartphone.

Various Return on Investment calculations and predictions and utility bills discussed during the interviews helped illuminate what kind of power was present in particular households, but were not used to compare households against each-other. In the period between interviews I kept in contact with the households over email, which consisted of short updates on system performance, added technologies, complaints about the weather and data on system performance, energy usage or calculated savings. This contact enabled me to ask for clarification on issues, which I spotted whilst transcribing interviews, or for particular graphs or calculations, which I knew people had but which I hadn't been given. A few of my informants who were particularly interested in the performance of their panels would send me updated calculations as and when then made them and one very dedicated informant still sends me information when he has new data or implements new technology.

In selecting the households my main criteria was the presence of solar panels, which the householder had invested in themselves. I excluded households which had solar panels installed by companies which provided free solar panels. As these companies offered householders free use of the solar electricity generated by the systems but not the income from the Feed-in-Tariff, I did not feel that these households would give me the full workings of solar panels as a domestic intervention. The initial literature review suggested although tentatively, that the dynamics of households which did not benefit from the Feed-in Tariff were different from the ones who did (Bahaj and James 2007, Watson, Sauter et al. 2008) which suggested that the payment of generation tariff was a powerful presence in everyday enactments of living with solar.

Despite solar panels being installed at a very rapid pace following the introduction of the Feed-in Tariff in 2010, recruiting households turned out more time consuming than anticipated. In my planning of the fieldwork I had first hoped to contact PV households through installers. This however did not happen as the installers I contacted were unwilling to facilitate contact to their customers. Instead I made contact to what became my informants through walking around in residential areas of particularly North Leeds, looking for rooftop installations. The cost of PV installation at the time averaged £10,000, which led me to focus on areas of Leeds I knew to be quite affluent. In 5 of the households recruited someone was at home during the day and I could introduce the research and myself directly. The rest of the households contacted me after I had posted a leaflet with information about myself and the research through their letterboxes. I posted a total of 40 letters through letterboxes (excluding three households who were at home when I called but declined participation). One participant contacted me because people who already participated in the research had given her my details and another one passed his details to a colleague at Sheffield Solar who had told him of my research. All research participants had new installations ranging from one installation, which was 6 months old to a household who had only just received a quote, which enabled my first visit with them to be on the day of installation.

As solar panels were clearly not attainable to the majority of the population in 2010/2011 (prices have fallen considerably since) I did not aim to have any particularly representative group of people. The people who participated were people who were interested in the research for one reason or another. They all shared an interest in learning more about solar panels themselves and the majority showed an interest in wanting to participate in sharing information about the practicalities of living with solar panels to other people. All 15 households fit a description of white middle class. Age-wise they ranged from a couple in their late-thirties with young children to a retired couple in their late sixties and early seventies. Despite my efforts at including both men and women and children to the extent possible, this ended up a somewhat gendered affair. Both husband and wife represented all households except three in the first visit. Of the three remaining one-person interview only one was with a woman. In the second round of interviews only half of the wives were present. Whether women were present or not during the visits however, there is a suggestion in the way that response from the households shaped itself, that solar panels, monitoring devices, spread sheet calculations and so on captured a more male imagination. This does not mean however that women were not involved. Fewer words captured by a recorder during an interview should not be easily translated into less engagement with the devices and flows of energy on a daily basis and it is important to consider this question of voice of respective genders also partially a matter of method and cultural convention. Unstructured interviews are great events for exploring 'unknown territory' and for coming across meanings and connections that are not determined by a particular conceptualisation or expectation or agenda on behalf of the researcher. But they are not democratic devices; they are not the best tools for the job if you want to make sure that all voices get equal say. So although I did put in deliberate questions in order to establish the dynamics of engagement with solar in the whole household, I did not have a problem with my recorder recording primarily the loudest voices. The following excerpt from my research diary sees me grappling with different ways of 'doing solar':

> **(Research Diary November 2011)** I came back from Simon and Clare's house with my head slightly buzzing from trying to contain and keep up with Simon's talk about models and data and comma-separated files. I see the fascination, I understand completely why you would get that into it. Solar electricity can be weighed and measured in so many ways and without, it seems, ever really grasping it anyway. I was a bit upset about Clare not being around for much of it. She kind of did the hostess thing and brought tea and cakes and then stayed for a few questions before leaving to go do something else. I got the impression that her engagement with solar electricity was different in kind rather than different in size. She was not bothered about models, but talked about her efforts to try and put stuff on and look out of the window to decide if now was a good time. As I am listening to the talk now I also notice that Simon often refers to *her way* of using it and to conversations and disagreements they have about how to do it, like when he was trying to get her to put white goods on after one another instead of at the same time. It made me think of Annemarie Mol and atherosclerosis. I think it is important not to equate time spent with depth of engagement here. They have different enactments, multiple energies: it takes a bit longer to enact solar as data than it does to enact solar as power to wash clothes, but I don't think that they are really comparative entities – or you can't deduct that he is therefore *more* interested than she is, rather they are just *differently* entangled with it.

I also include in the UK ethnography an analysis of the contents on Sheffield Solar's Microgen Forum. Sheffield Solar launched in 2010 as part of Sheffield University's

Project Sunshine and is funded by the Higher Education Innovation Fund to promote links between industry, society and academia. Sheffield Solar involves 2 sub projects: the Solar Farm and the Microgen Database. The Solar Farm is a $58m^2$ silicon photovoltaic solar panel installation at the university, which includes a test bed to compare new and existing photovoltaic technologies, carrying out laboratory testing on real world application. The Microgen Database collects and reports back on performance data, which is donated by PV users nationally, allowing them to see how well their system is performing in the context of others in their area and across the country. Having initially provided details of their installation including system specification, orientation and tilt angle, monthly readings are calculated at Sheffield Solar and appear as a monthly performance report and a newsletter which is sent to all data donors, and available online. The forum includes an estimated 200 users from across the country, but with a large proportion of users from around Sheffield, including 4 of the households involved in my ethnography. The Microgen forum is dominated by conversation between a small numbers of "regulars" who have been loyal users of the forum for a long time. (It has not been possible to determine the exact number of regulars, my assumption based on my analysis of posts is around 50 people). Users most often know each other by first name and will refer to a shared history of previous threads and conversations had before as well as links outside the forum to other forums or monitoring websites, when they are commenting on issues raised on the forum. Although accessible as an open forum, the Microgen Forum functions more as a semi-private community of enquiry, certain elements of which resembles those known in urban laboratories (Evans and Karvonen 2013, Karvonen and Heur 2013). I engaged actively with the forum as a user (having made my role as a researcher and my connection to Sheffield Solar known), and would both observe conversations, comment and initiate threads myself. With a few exceptions, the forum is a predominantly male environment as well as an environment where the majority of users are familiar with calculation and for some also techno-science. It was a forum where, in order to be taken seriously, I had to make use of some of the technical insights gained during my time at the physics department and Sheffield Solar.

After giving a presentation at the Future build conference at Sheffield City Hall in 2014, where the majority of the audience came from either solar industry, construction or policy backgrounds, someone in the audience made a comment about the forum users and their engagement with solar: *"but surely it is not everybody who has solar panels who puts this much effort into it, don't you think that these people are a bit unusual like that?"* My response to him was something like this: 'Of course I cannot know what people I haven't spoken to do, we don't know much about this, but I think you are probably right, they might not be particularly representative of the greater solar population. But what I think these people can show us is not so much something about the solar population, but rather something about what happens when you engage with the technology at this level. They tell us something about themselves, but more importantly they tell us something about the technology. A lot of these guys are perfectly happy with the term "geek" if used respectfully, and that is in a way the role I think they have in my research: they occupy a particular space between scientific enquiry and everyday engagement and in this space there is still a lot to learn about how this stuff actually works in real world conditions'. At this conference I stopped short of going into academic references, but what I was of course thinking about here was Michel Callon and his notions of "research in the wild" (Callon and Rabeharisoa 2003) and "hybrid forums" (Callon, Burchell et al. 2011). Solar users in this research are not objects of enquiry in a straightforward manner, but rather *assistant researchers in the wild* who investigate, as do I, solar panels in action in everyday life. In the following chapters I will show how solar PV technology is installed on the roofs of UK households as a fit and forget technology or what the STS literature calls a black box. The users on this forum illustrate how solar panels in techno-science are not the same as solar panels on a roof in Barnsley. And that their political and economic packaging which was intended to bring certainty sometimes overflow into proliferating uncertainty (Callon, Burchell et al. 2011). These people put a lot of effort into investigating what is inside that black box. As such they are important research collaborators in this ethnography. Whilst the majority of the households who participated in my ethnography had only recently installed PV systems at the time of my first visits in 2011, the majority of users on the forum had already had their panels for some time, when I began investigating the forum in 2013. Between the households and the forum users this material then provides a qualitative insight into the processes through which people learn to live with the technology during the first 3-4 years. But because my focus in this research was about what solar panels do rather than what people do, I wanted to see how their performances compared and contrasted to solar panels in different places. In the following section I look at solar panels in Sri Lanka.

3.4.3 Solar Panels in Sri Lanka

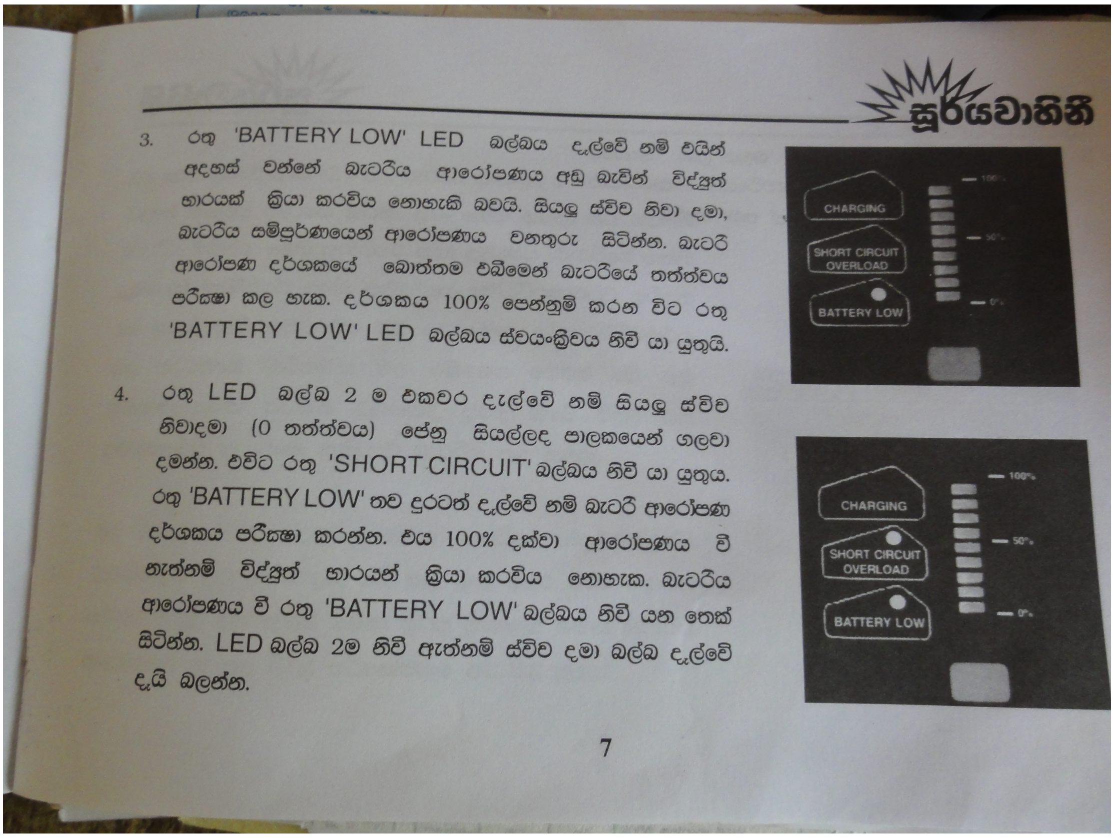

Figure 3-2: Instruction booklet from Solar Home Systems in Sri Lanka

The decision to include Sri Lanka in this research was made as a result of the initial literature review during the first few months. As has been noted, focusing on or following a device or a thing might do this: it might mess up the categories and disciplinary boundaries which order academic enquiry (Latour 1993, Cook 2004). I had found solar panels in accounts of everyday life in developing countries and I was struck by the differences in how the technology was considered, investigated and held accountable in the different literatures. For an enquiry which has a device at its centre, and which investigates the manner in which it makes itself at home in different places by “following it” (De Laet and Mol 2000, Cook 2004) to different places, context becomes an achievement rather than a constant and pre-existing reality. This makes Sri Lanka and the UK not so much locations where solar panels were *rolled out*, but locations or situations which became *enrolled* by solar panels. Choices about who to talk to and where to go were then made not in a manner to achieve comparative alignment between the two places, but rather following this question of what or whom was being enrolled locally.

The choice of Sri Lanka involved both considerations based on literatures and a certain degree of serendipity. In 2011 Sri Lanka looked like a success story for solar. The World Bank funded Renewable Energy for Rural Economic Development project (RERED) had been running for many years and sold a lot of Solar Home Systems (SHSs) (WB 2007), Damien Miller published *Selling Solar* which portrayed the country as a success story for solar diffusion (Miller 2011). It offered both a history of solar diffusion and a reasonably large amount of Solar Home System owners to go and visit. As I was researching this and comparing different contending places to go and investigate Solar Home Systems I went to a talk by I.M Dharmadasa, Professor of Applied Physics at Sheffield Hallam University. Professor Dharmadasa leads the Electronic Materials and Solar Energy (solar cells and other Semiconductor Devices) Group at Sheffield Hallam. As well as that he is originally from Sri Lanka and has been involved in setting up a solar powered water pump in the Sri Lankan village of Kaduruwewa in the North Western District. The talk was about the installation of the solar pump and Professor Dharmadasa became an important gatekeeper, as he was able to introduce me to important solar contacts in Sri Lanka.

As preparation for fieldwork in Sri Lanka went on I relatively quickly managed to get contact with and set up meetings with contacts in senior positions in both RERED project Administration and the Sri Lankan Solar Association. Further planning was difficult to make, it is of course in the nature of rural villagers who use Solar Home Systems that they are difficult to get hold of from the other side of the planet. Instead I trawled various expat communities and Sri Lanka related forums online and made contact with a number of people who agreed to help me once I was there. One of these, a UK born Sri Lankan Tilak Conrad, owned a coconut plantation in an area where there were many Solar panels and became another important gatekeeper for me. With these contacts and provisional areas to visit I went to Sri Lanka expecting to do much the same as I had done in Leeds: go wherever I could identify a solar panel.

At this point in the ethnography I was somewhat tripped up by the fluidity of solar panels in rural Sri Lanka. At the beginning of 2012, solar panels were harder to find in Sri Lanka than the literature I had read in advance had led me to imagine. This led to two realisations. Analytically it foregrounded the temporal performances of Solar Home Systems in Sri Lanka: unlike the solar panels in the UK which were expected to stay in place for at least 20 years, solar panels in rural villages in Sri Lanka, I soon learned, rarely stayed in place and in operation for more than a few years. Methodologically it meant that my methods had to adapt. Realising that solar panels did not in fact live and stay living in great numbers in villages in Sri Lanka meant that considerably more time had to be spent identifying solar panels. And of course searching for solar panels in rural Sri Lanka is a lot more time consuming than walking along nicely paved residential neighbourhoods in Leeds. Boundaries around field-sites not least in out of the way places are not always as neatly organised as might be expected (Tsing 1993, O'Dell and Willim 2011). The process of adapting methods when encountering obstacles is a necessary part of doing ethnographic research, which involves working not only methodologically with choices about how to best achieve a certain kind of information, but also negotiating a number of more or less conscious imagined geographies. The following excerpt from my research diary sees me grappling with this this in the initial stages of "culture shock", and provides a picture of the process of doing ethnography as a dialogical and affective process of improvising theory (Cerwonka and Malkki 2007)

> **(Field Diary, February 2012)** I have armed myself with all sorts of plans about how to gain access to people in villages, how to talk to people, what to observe, how to order and code observations etc. As I write I know that I am in that famous state of culture shock, which happens at the beginning of fieldwork. I have expected a certain amount of uncertainty and confusion. I somehow never really prepared myself for exactly this situation: I have no village! I mean what kind of ethnographer am I if I can't even find the village?! Instead I appear lately to 'go to (field-) work'. I get up in the morning, get the train to Colombo to meet somebody and then I come home from (field) work in the evening. I get this feeling that somehow I am cheating here. I have a fridge and at this point in time my son is watching Tom and Jerry on some Indian channel on satellite TV, whilst I am writing this on a laptop in a well-lit room. I'm pretty sure this did not happen to Geertz!

This excerpt is of course the kind of stuff that gets written out, before ethnographic material is published. Being under prepared, naïve and overwhelmed by heat and culture is rarely celebrated much. But it is important to include nevertheless, because it shows the messiness of doing ethnography and the degree to which improvisation and adjustment which happens as a result of being in particular contexts which can never fully be anticipated in advance happens in 'nervous conditions' (Cerwonka and Malkki 2007) and are learnt not once and for all, but again and again. It also shows how different methodological expectations exist more or less consciously connected to different places. Reading this a few years later it is becomes obvious that the manner in which I ended up doing fieldwork in Sri Lanka was very similar to the way I had done it in UK – but without any anxiety about sleeping in my own bed. Ideals about how ethnography ought to be done are on the one hand very fluid, but on the other hand very much situated in literatures, which relate to enquiries carried out in particular empirical locations.

Steering my way of this particular road-block of culture shock and great ethnographic literatures was greatly helped by reading Anna Tsing's *The Diamond Queen* (Tsing 1993), and being reminded that I was not the only ethnographer who had failed to find a village. This gave me both comfort in my own abilities as a researcher and faith in my subsequent methodological choices which resembled very much the kind of 'walking ethnography' Anna Tsing had also chosen (Tsing 1993). If panels did not live in villages, this was not going to be a village-study, ethnographic methods had to adapt. Thinking things much more along networks and trails (Ingold 2011) than the geometric spaces I had stumbled over in this phase enabled me to carry on my ethnography very much in the same manner as what I had done in the UK: I simply went looking for solar panels. Working through these different circumstances and indeed different practical challenges having already done part of my ethnographic enquiry in Leeds made me increasingly unsure on the one hand of a notion of methodology as an immutable mobile and surfaced on the other hand questions of what kind of work needed to go into the achievement of comparable entities – questions I shall consider in more depth in the following section. During the 5 months between January and May 2012 I carried out my fieldwork in Sri Lanka centred predominantly around a number of villages in the 3 provinces: North-Western province, Uva and Central Province, along with Colombo (in the Western province) for most industry and project administration interviews. The North Western and Uva provinces are mixed dry zones and intermediate zones, whilst the Central and hilly zone is the wettest in the country, a geographical difference which mattered greatly for when and in what way Solar Home Systems were sold and operated there.

With only a small budget for translation I relied on a number of different assistants which I recruited locally: these were sometimes local students, one was an English tutor but very often in some of the most rural areas I would rely on hiring the driver which had the best language skills I could find (I return to the issue of translation in the following section on collaborators).

Getting access to villages required a lot of talking to many people in order to establish contacts. Once households with solar panels were identified I would approach them and ask if I could talk to them about solar. Although it was difficult to find the solar panels in the first place, not a single SHS owner said no to participating in the research – at least once it was clear that I had not come from the Bank. In the beginning I had my recorder with me and recorded the conversation during these visits, but they were more obvious in this context than I liked and came with problems of poor battery quality which made them stop working on a couple of occasions. Having transcribed the first few, which involved listening through a lot of Singhalese or Tamil, which I could not decipher, I decided to adopt a more 'old school' approach and simply take notes. Sometimes as we spoke, sometimes in the tuk tuk which I asked to just pull over for a little while on the way back from the village, sometimes in little roadside restaurants and sometimes back at my own ex-pat style house with electricity, laptop, electric fan and all.

The much more ad hoc nature of these visits to villages made it difficult to keep exact track of how many informants I spoke to and for how long. During the 5 months I visited 14 villages and spoke to somewhere in the region of 50 SHS owners as well as 5 previous and one active installers and 8 people otherwise involved in the RERED project, Sri Lanka's Sustainable Energy Authority or the solar industry. I also spoke to a lot of other people: some informants I only spoke to for the amount of time it took to prepare and drink a cup of tea. Some I spoke to several times over a period of days. Some informants I spoke to in their own houses, others joined the conversation in other houses or at the little shop in the village. One informant worked at a guesthouse I stayed at and we spoke there (with the help of an English speaking Sri Lankan guest who was interested in solar panels). And of course the quality of the conversation in terms of how many words were spoken and understood varied with different translators.

As Wilk has suggested, the lines between what is external or internal to ethnography and private life very often get blurred (Wilk 2011), which was the case both in the UK and in Sri Lanka. Learning to focus less on how long and under which conditions I spoke to whom, and more on what was said or seen was something which developed as I became increasingly accustomed to the different enactments of solar panels I encountered.

Doing ethnography in two very different places meant, as already indicated, that my curiosity about the adequacy of certain notions of methods became increased as I began to doubt how well methods travel, not merely geographically, but also in methods literatures. The following section is therefore concerned with how I 'did ethnography' in conversation with both conceptual and methodological literatures and empirical encounters.

3.5 Irregular ethnographies

As outlined in the previous section the two geographical locations involved in this ethnography were different not merely in and off themselves but as ethnographic challenges with different issues in terms of access, language, and ability to plan and recruit participants in advance. The differences between the two sites could to some extent be incorporated into methodological considerations made before fieldwork began and was anticipated in different ways: ethnographic methods needed to be fluid and adapt to the particular field sites in this ethnography as much as in any other ethnography (Massey 2003, Wilk 2011). The purpose of this section however is to illustrate how planning and adaptation of methods continued as both fields unfolded and how the process of doing and improvising ethnography (Cerwonka and Malkki 2007) came to shape not only findings but also theoretical understandings of what, where and when ethnography is. Writing ethnography cannot be easily separated from fieldwork and certainly has not been in this research, as already suggested. Writing has performed an important part of analysis and frequently insights about how solar was assembled in one place would come about exactly whilst writing about how they were assembled in another place. The sub-sections to follow are concerned with how notions of data (section 3.5.1), experiment (3.5.2), adjustment (3.5.3) and collaboration (3.5.4) were assembled and re-assembled during the ethnography, in entangled processes of fieldwork, analysis and write-up.

3.5.1 Doing ethnography and the trouble with data

In the context of ethnographic research methodology, Tim Ingold has written about the experimental character of anthropological approaches to fieldwork in relation to other social science approaches as a difference in scientific protocol. Experimentation, Ingold contends, is fundamental to anthropological inquiry, which places the research not on the outside of a phenomenon, but in the midst of it.

> "In terms of scientific protocols, these experiments break all the rules. That, perhaps, is why anthropologists are so shy about owning up to the experimentality of their discipline, and why they shelter behind the pretence

> that far from joining with the people among whom they work in a search for answers to the fundamental questions of life, all they are doing in the field is collecting data…" (Ingold 2011: 16)

It is perhaps questionable whether the rules for social science enquiry are indeed as easily assembled into one as Ingold assumes here, but what is important here is Ingold's focus on the process of enquiry, the *doing in the field*, which according to him is insufficiently understood by the term "data collection". The notion of data collection is an important metaphor to consider and one that becomes particularly acute when different locations come to disrupt the idea of data being somehow readily available for the researcher to collect. In the process of this field-work it became at times very clear how data was not collected, but *achieved* (Latour and Woolgar 1979), not once and for all but through reiterating processes which went on throughout the process. The notion of a rodent-model of data collection – as a squirrel finding nuggets of evidence ready for collection and categorisation, was never a good metaphor for the knowledge practices involved in this research(Pryke, Rose et al. 2003). Instead Sarah Whatmore's contention that: "ethnography, can be argued to come the closest to the notion of 'generating materials', as opposed to 'collecting data', of any method in the social sciences" (Whatmore 2003:93), provides a much better image of what doing fieldwork was in this thesis.

This move away from data-collection towards data-generation of achievement further challenges the view of the lone researcher finding and collecting data on her own. The question of how to do ethnography in a manner which moves away from a reliance on human intentionality and embraces more distributed forms of agency is closely related to this (O'Dell and Willim 2011, Tsing 2014). Appreciation of the distributed achievement ethnographic data is, enables an openness to how particular forms of agency such as electric power and photovoltaic technology are subjects which *force thought* in particular ways (Stengers 2010) and thus shape the enquiry. In the following subsections I consider in more depth what a notion of generating materials rather than collecting data does to the process of doing fieldwork, by describing my experience of carrying out ethnographic enquiry using the image of experiment rather than collection.

3.5.2 Ethnography as experiment

The methods used during my fieldwork relate to my ethnographic training, to methods literatures, and to famous anthropological accounts from out of the way places. In relation to all of this there are a number of tools I could refer to by saying that I have done in-depth interviews and participant observation, which I have. But that wouldn't really cover what doing ethnography is: there are many ways of doing in-depth interviews and participant observation, asking one question instead of another, paying attention to one event more than another. Ethnography is a set of encounters, which it is difficult to account for theoretically, and independent of empirical context. So rather than produce a list of different methods employed in order to gain information, my understanding of ethnographic practice follows Richard Wilk's words, that

> "Ethnography cannot be found in the practice of fieldwork, but in the attitude and values one brings to many different kinds of work. The visible techniques of asking, answering, recording are much less important than the hidden technologies of distancing, re-learning, seeing the commonplace as unusual,

finding telling details and gaps, an awareness of qualities and categories in addition to numbers and things' (Wilk 2011).

Whilst ethnographic enquiry is not the only one, which seeks to employ such techniques, it does so in a particular and empirically situated manner: what Wilk suggests here, is that ethnographic methods cannot be completely separated from the ethnographer. A recent special Issue of Ethnologia Europaea themed *'Irregular Ethnographies'* (Ethnologia Europaea, 2011 41:1) has called for a more nuanced discussion of what ethnography is today, where the notion of taking a year out to conduct fieldwork is more an idealized notion than a reflection of academic reality, and where all manner of technologies and techniques, such a multi-sited ethnographies, art-related practices, visual ethnography and auto-ethnographies have fundamentally challenged the idea of ethnography as a mode of systematic investigation (O'Dell and Willim 2011). More time does not equate more depth in any straightforward manner. The underlying notion that restricted access to the field (temporally or otherwise) in ethnographic fieldwork is an exclusively new phenomenon can be contested (Massey 2003) and you can certainly question whether there ever was such a thing as a regular ethnography which did not include any access issues, but what this volume very importantly brings out is the question of what happens *during* fieldwork. It particularly focuses on the doing of ethnography, the "challenge to choose, mix, and compose a feasible result from an overwhelming array of analytical components, generated from a "field" which might not be as regularly delineated as textbooks would have us believe" (O'Dell and Willim 2011:10).

Whilst this is quite far from an image of spotting and collecting data ready for inspection, a different kind of image of process of scientific experimentation provides a better metaphor here of what doing ethnography is like: as a process of setting up, tuning, adjusting and making specific cuts, excluding and including specific components in an empirically situated activity. And what this image also emphasizes is exactly the kind of 'Joy of not knowing' referred to in the beginning of this chapter: The capacity of ethnographic methodologies to surprise the researcher and destabilize theoretical or analytic assumptions is not it is argued a side-effect of the method, but part of the process. As briefly mentioned before this is an area where my experience of knowledge practices within physics has greatly influenced my analytical thinking. So where the image of collecting acorns provided a poor fit to my experience of doing ethnography, the image of moving mirrors, aligning pieces of polymer and Adam leaning on the spectrometer in lab 2 because he knew that it had developed a tendency to be slightly misaligned through wear and tear, became an increasingly more fitting image of my knowledge practices.

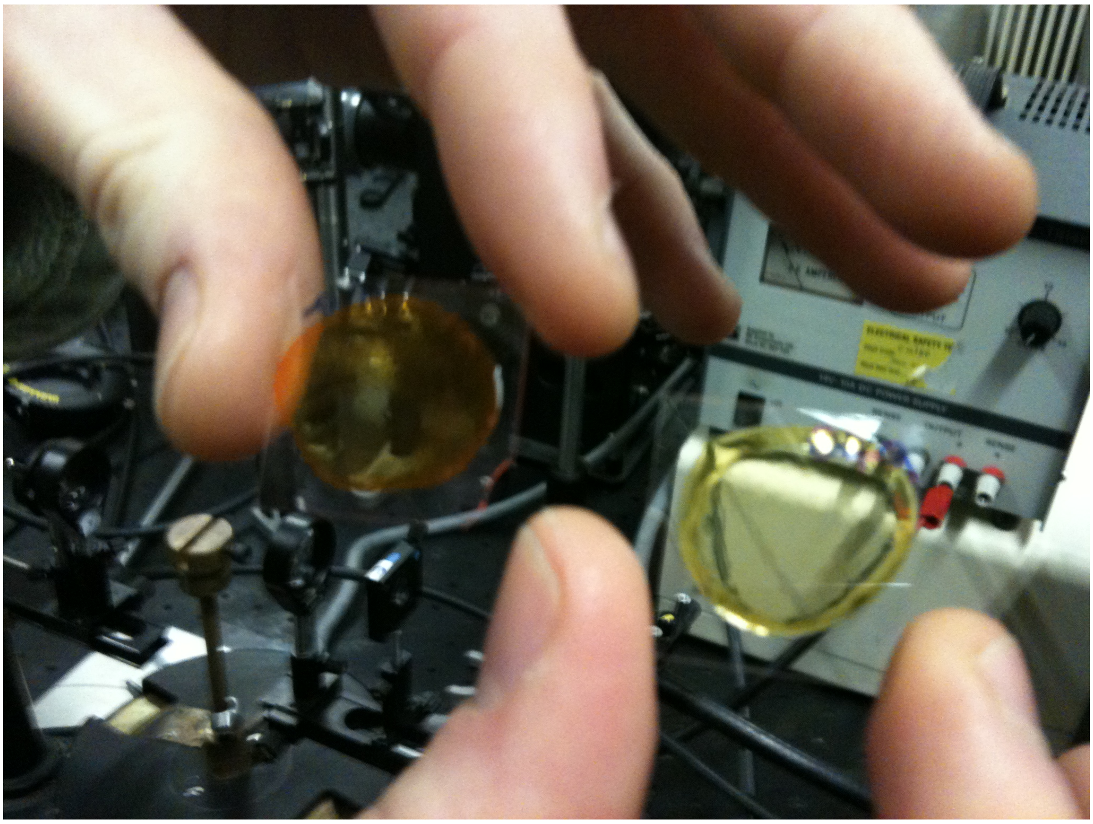

Figure 3-3: Green laser experiment with synthetic dyes, Sheffield University

Seeing ethnography as experiment or as a particular situated and continual way of ordering the world, means that the description of ethnographic methods cannot simply focus on fieldwork as the process of being in a place whilst gathering information about this place. Ethnography in this thesis was not merely the application of a set of context independent methods of enquiry, but rather the tuning of these in intra-action with both a particular object and a particular position in time and space. It was further a tuning which was not only internal to the situated enquiry but also in response to the diffractive relationship with the "opposing" field site. The ethnographic material achieved in Sri Lanka was very much influenced and shaped by the fact that it happened after a period of investigation in the UK, and the second part of the investigation in the UK very much influenced by the fact that it happened after a visit to Sri Lanka. Or to put this more empirically: As I encountered the first 40 watt Solar Home System in Sri Lanka, I did so with both analytical and ethnographic experience of what a 4Kw system was capable of assembling in everyday lives in the UK, which was again informed upon my return by the particular issues brought out by the insights achieved in Sri Lanka. This temporal entanglement of sites meant that any correlation between time spent and depth of enquiry achieved was never going to be that straightforward. Whilst the spatiality of the two places makes it possible to consider them different ethnographic encounters, their entangled temporality blurs the picture of *when* insights were achieved about specific sites. Considering the places I visited during this PhD then not so much as separate *field-sites* but more as the emergence of a heuristic *field-world* where the overflows between the individual sites were not so much problems which needed to be overcome but performative components of analysis, makes the doing of ethnography a performance in time as much as in space.

Attending more closely to the experimental nature of fieldwork, draws in the agency of the researcher in a manner, which is perhaps, more acute than is the case in the 'data collection' understanding of fieldwork. Karen Barad's notion of intra-action as discussed in the literature review makes a useful contribution to thinking about fieldwork as experiment. Referring to Ian Hacking's critique of representationalism, particularly his thoughts on experimentation, Barad suggests that "experimenting and theorizing are dynamic practices that play a constitutive role in the production of objects and subjects and matter and meaning" (Barad 2007: 56). Doing fieldwork, experimenting and theorizing, is a material practice, it is more than a discursive ordering of the world, it is an intra-action. As such it is a process, which I feel deserve more scrutiny. This is not because the processes of doing fieldwork which often get written out of finished results as illustrated by Sarah Whatmore's quote earlier in this chapter are suspect, but because leaving them out is leaving out an opportunity to understand better how distinctions between objects and subjects (or the orderings of these into ontologies and epistemologies) matter. Accounting for the particularities of this ethnography is entering a territory of adaptation, improvisation and learning *with.* Ian Hacking I think has described the process of experimenting in a manner, which frames my experiences of doing fieldwork nicely in saying

> "Most experiments don't work most of the time. To ignore this fact is to forget what experimentation is doing. To experiment is to create, produce, refine and stabilize phenomena…but phenomena are hard to produce in any stable way. That is why I spoke of creating and not merely discovering phenomena. That is a long hard task" (Hacking 1983: 320)

3.5.3 Adjustments – tuning the lens

Karen Barad's notion of phenomena which only exist in intra-action with a particular apparatus put to work on solar panels illustrate how solar panels in use can perhaps not be made sense of using the same concepts irrespective of the particular set-up that has put them there. Solar panels, which are technologies in order to reduce carbon emissions in one place, are not the same as solar panels, which are technologies in order to improve quality of life in another. Reading these differently enacted solar panels diffractively enabled certain aspects of their everyday agencies to become foregrounded, but foregrounded also the conceptual frameworks, which accessed them. Empirical experiences can turn things upside down, like that. Marilyn Strathern is known to have emphasized and utilised this capacity of ethnographic practice (as noticed by de Castro and Goldman):

> "Either we simply apply the notion of network to the Melanesians – this is the traditional procedure in anthropology –or we do what Strathern does, which is exactly the opposite: apply the Melanesians to the notion of the network, that is, we redescribe the concept of network with the help of Melanesian realities. Everything happens as (if she were to say) the following: 'If Melanesians had the will and the patience to read Latour, what would they be able to say about it?" (Viviero de Castro and Goldman 2009, withStreet and Copeman 2014: 13).

Of course empirically this is somewhat less neat. This ethnography has involved some very differently situated solar panels, which speak in a less unified voice than Strathern's Melanesians above are assumed to do. So making sense of solar panels in the field was indeed, as Tim Ingold has suggested, a matter of "tracing multiple lines of becoming" (Ingold 2011), but it was also very much about making particular cuts (Strathern 1996) and negotiating absences and presences (Law and Singleton 2005). Lines in other words are not just there in and of themselves, they are made, In practice ethnographic fieldwork is a lot less about observing clearly delineated lines and a lot more about making your own trails, not once and for all but continually throughout processes of being in the field and sitting at a desk writing the two solar assemblages up against each other. Adam's green laser experiment became an important means of thinking this: different components in the research apparatus would momentarily block the experiment, and would need to be aligned again before the experiment could say anything at all. The blocks in this research could be practical ones, difficulties to do with access for example, but increasingly as the process of "applying the Melanesians" gained momentum, they would also be conceptual ones. Attempts at separating causality and discourse, ontology and epistemology did not clear things up (Barad 2007).

Thinking of ethnographic experience as experiment or as processes of creating materials rather than collection data draws in more than the role of the researcher in setting up the experiment. The STS literature has provided a rich literature on experiments and how scientific facts come into being through the organisation of and collaboration with a great number of both human and non human assistants and collaborators (Latour and Woolgar 1979, Latour 1987). Extending the notion of experiment to ethnographic practice enables some of those insights to be used on the processes of doing fieldwork, which makes it possible to turn the gaze the other way, from the achievement of research findings to the achievement of "the researcher". Inspired in particular by Latour and Woolgar's meticulous attention to detail and distributed agency in their laboratory studies (Latour and Woolgar 1979), it becomes necessary to consider the collaborative nature of the process: not all lines are planned in advance and not all of them are set out by an individual researcher. Following this STS literature, and accepting Bruno Latour's analysis that Louis Pasteur did not singlehandedly discover the principles of vaccination and pasteurization, but rather occupied a particular place in a heterogeneous and historically situated network which had many more participants (Latour 1993), it becomes important to ask about the network of forces and participants which enabled me to assemble my analysis in the manner I have. This is a big question and unravelling an entire network is of course neither possible nor potentially very interesting. Instead I wish to just introduce two events in which it was clearly not just my planning and methodological strategies, which set up experiments. The first example comes from working with a particular translator in Sri Lanka and the second from working with PV monitors in the UK.

3.5.4 Collaborators

Whilst Tim Ingold's notion of trails of becoming might give you the impression that he imagines trails to be empirically already present in the field, Marilyn Strathern's notion of creating tangents (referred to earlier in this chapter) is perhaps a more appropriate representation of the processes of finding your way through ethnography. There is not always an obvious trail so creating tangents is rather more a matter of making lines through points which seem connected or in the general direction of something which is not currently in view. Creating tangents and making lines of course does not happen in worlds, which stand still whilst the researcher deliberates her next move. Working with translators in Sri Lanka came to illustrate how much it was a matter of collaboration. Translators are no longer expected to be merely mediators who do not shape enquiry, and I never expected them to be. The impact of working with translators however was not just a matter of factoring in the quality of the translation in terms of neutrality or "truth value", but a matter of considering what kind of collaboration was going on between different and differently involved parties, often given titles such as the interviewee, the translator, the researcher, the camera, the notepad, the setting and so on (O'Dell and Willim 2011). There was by no means a direct correlation between working with proficient English speaking people with experience of translation and a lot of insight/ knowledge being produced. Instead the disruption of one way of working was as much a creative challenge and affordance as it was a simple problem or roadblock. I did some of my best observations of non-human agency travelling with Isuru who was a nice, chatty man but a truly disastrous translator who would summarise rather than translate what people said, making it very difficult to proceed with a method of unstructured interviewing which is reliant on "words in between" to create tangents for new questions. Because some of this, those interviews became more structured with greater reliance on pre-determined and less exploratory questions. Where my reliance on wordy worlds (Crang 2003) was therefore lessened, my attention to details like what kind of artefacts were present in the household was heightened and patterns emerged less out of repeating narratives and more out of repeating assemblages of *stuff*.

Collaboration from translators did not just influence how I asked questions but also which questions were asked. In the area around Nuwara Eliya in central Sri Lanka, I spent a few weeks working with a tuktuk driver who called himself Lucky (which was phonetically close to his Sri Lankan name, which he explained always confused foreigners, so he had discovered that the English word Lucky was a close match). I met Lucky when he first took me into town to go to the market and I discovered from our conversation that he spoke good English. He was also eager to show me his "review book" (which many tuktuk drivers who spoke good English and lived in areas with enough tourists to specialise as tourist guides often had, with reviews from previous foreign customers) with a comment from a German researcher he had previously translated for. Over the next couple of weeks, Lucky became a very passionate research assistant. A few days into us working together we went to an area 30 minutes drive outside Nuwara Eliya, which had been particularly badly affected by the activities of desperate and unscrupulous solar vendors during the last few years of the solar boom and bust. Having not previously been aware of the issues around solar and not knowing personally anybody living in rural areas, getting to know about this caused Lucky to become touched by the stories he was conveying to me. The following excerpt from my field diary is from a day where I first got increasingly frustrated with him for forgetting to translate the answers people gave, and for asking his own questions without translating them to me, until I realised that what I was getting instead was access to a different side of things, namely a second reading of the situation. We are visiting a household who has lost a lot of money by being sold a soon malfunctioning panel which the microfinance bank eventually came and took away as the family, upon realising that the vendor was not coming back to repair it, had stopped paying for.

(Field diary, May 2012) *"They say it happened to a lot of families"* says Lucky *"and they never got any receipt or anything so that's why they are not even sure if they were actually from the Bank! I said they should have called the Police".* Lucky is clearly upset and angry and has started asking his own questions, forgetting to translate. I know that the RERED had a complaints procedure, but that most people weren't told about it, so I ask if they ever complained? They show me a postcard, it's written in Sinhala script and they say it is to send a complaint. But there is no address on it; they don't know where to send it! Lucky is furiously throwing his arms up in the air talking a mixture of Sinhala and English in order to express his outrage at this situation.

We are about to leave the house. Again there is lots of animated talking and I am getting frustrated with Lucky for not translating. Eventually I realize that the important thing here might not be exactly what words are said, but how they are expressed. I observe. The intensity of the communication, the clearly angrily animated body language and just the sheer speed at which people are talking is not usual in these conversations in people's houses. After a while Lucky turns to me and says, *"I'm sorry Ma'am. They are so happy that you have come and asked these questions, because nobody cares what happened to them. They lost all this money and no one can help them. I'm sorry ma'am, I told them that you would tell your government about it!"* There is a time for analytic distance and then there is a time for affect and the division of labour between myself and Lucky on this front had just tagged into a much more critical perspective on the events of particularly the latter part of the RERED project, than I had previously encountered. As we followed up on 'Lucky's investigation' a new picture of what solar panels also did emerged and whilst my analytical distance perhaps prevented me from reacting as strongly as Lucky did, seeing this situation diffracted through him made solar panels look slightly different from that day on.

An important methodological requirement in this thesis was to develop ways of understanding the intra-action of matter and meaning. Understanding material dynamics and politics after all hinges on the ability to understand how non-human forms of agency shape, afford or prevent particular worlds in non-verbal manners. Of course non humans are part of all ethnographies and their capacity to order worlds have in many senses always formed part of ethnographic narratives (Tsing 2014). The added challenge with an STS inspired approach is how to include them without appointing them, as is often the case, a role where they assert merely effects on human beings, but remain explanatory props in accounts that are at the end of the day primarily concerned with what people do. Jane Bennett has suggested that it might be worth running the risks of anthropomorphizing, as this may work against anthropocentrism, because "a chord is struck between person and thing" (Bennett 2010: 120). This goes somewhat further than the notion that we come to know about the world because we are in it (Ingold 2000) and is related to Donna Haraway's ideas about 'having truck' with something (Haraway 2008). It is not unusual for ethnographers to develop stronger bonds with some research participants than others, Anna Tsing's relationship with the Diamond Queen being a particularly striking example (Tsing 1993), neither is it unusual for researchers to come to care for technological devices, de Laet and Mol's love for the Zimbabwe Bush Pump (De Laet and Mol 2000) and Latour's thoughts on relationships between technological devices and their creators seen through a failed transportation system (Latour 1996) being nice examples of this.

The experience of striking a chord more with some research participants than others is not at all an unusual experience in ethnographic research. The suggestion that there might be a certain purchase in trying to draw on the kind of abilities to do this or to have truck with research subjects which most ethnographers recognise from engaging with human subjects, to engagement with non-human ones, has in particular one consequence which I think is both problematic and really promising: it opens up the process of *doing* ethnography, and asks for accountability in relation to it. The kind of scholarly categories which once made it possible, and comme il faut to have an orderly and separate record of field notes (data gathered in a particular place) and a field diary (the researchers personal thoughts and feelings), as Richard Wilk has described nicely in his account of doing fieldwork in Belize in the 1970s and onwards (Wilk 2011), becomes suspicious as it is exactly the relationship between the two – how the researcher comes to have truck with something which needs accounting for.

An example of such a process of having truck with or coming to care for particular devices during my fieldwork because of their impact on my enquiry can be seen through the following notes from my research diary, which describe the process during which PV monitors became not merely objects of conversation, but also as research informants which could tell me things about flows of electricity which people could not, and which prompted me to pay more attention to the temporality and the specific patterns of power within the household than I would have done without them:

> **(Research diary, November 2011*(in italics*)/August 2014)** When you talk to people about energy and what they do with it in everyday life, they most often think you want to hear about energy consumption. Reading through my old research diary posts this is quite obvious. I would say that I was interested in

solar energy in daily life and people would start talking about consumption. So for a while so did I. I also read about consumption in the literature. The trouble was the painful silences at the first couple of visits, after people had explained how it impacted on their energy consumption. That bit was kind of over very quickly and it somehow led to no-where. I took me a while to work this out. I wrote in my field-notes after the first house visit in 2011:

'I was sitting there, on my hands, desperately trying not to fill the space, not to ask a question too soon to fill the silence but just wait. It was painful. I felt like I had just asked them what it was like, now that they had a new front door… there wasn't much to say. There wasn't much to see. 'Move on, there's nothing to see here' I thought. I emailed Nicky who said 'what does the silence tell you?' At this point in time it doesn't tell me anything. Nothing happens!'

Still at the beginning of my field-work with all the insecurities and questions that this entails, the worry that I might not ask the right questions, that I might never discover anything of interest, did not enable me to see beyond the silence, or to see some great significance in it. It was not so much the silence as two devices, the voice recorder and the PV monitor, which moved things forward. A few weeks later I was transcribing the almost one and a half hours of recording from that first visit to Matt and Eve. I wrote in my research diary: *"It's just about the time when I first ask about the monitor. There is a change in the conversation. The talk about consumption kind of grinds to a halt, and I can't think of anything else to ask. But out comes the monitor and the conversation goes on for another hour and a bit! I can't believe I didn't see this, it was the same thing talking to Martin: if you ask about consumption you fairly quickly get this silence where there just isn't anything more to talk about. The monitoring however, the numbers, the little methodological miracle that is the Sunnyboy wireless monitor! You cannot talk*

> *about energy consumption, this is not the force solar has, but here, look here are the flows of energy themselves! This is what people live with - Eureka - I have seen energy! It might be invisible under the framing of consumption, but it is definitely visible through the Sunnyboy!"*
>
> Of course the wonder of the Sunnyboy does not stop there. Almost 3 years later I am now sitting here with all Simon's graphs, printed and laid out to show me the movements of a month's worth of solar activity. Simon's sunnyboy is not just a prop, it is a research collaborator, which has just visualised for me the complete chaos that is domestic solar generation: these curves are all over the place!

Non-human research participants, just like human ones move to and fro categories of what is being researched and who/what is doing the researching, and it is in this process that I came to have truck with the PV monitors, not merely because they had agency that I could account for, but because their agencies disclosed worlds to me: worlds of human beings relating to them and worlds of electricity flowing in and out of households according to them. Another detour to my experiences in physics help frame this situation, namely another conversation with Adam in which he helped me get to grips with Niels Bohr's complementarity theory: that we cannot know both the position of an electron and its momentum at the same time. This is not a matter of properties of electrons per se, but rather a matter of the specific apparatus needed to establish either. Knowledge about electrons is not independent of that, or " The boundary between the 'object of observation' and the 'agencies of observation' is indeterminate in the absence of a specific physical arrangement of the apparatus" (Barad 2007: 114) In this movement between object of observation and agency of observation – I prefer the term research collaboration for the latter, I came to have truck with the Sunnyboy monitor and a number of other things whose role in this research is not adequately understood by the notion of objects being handled.

3.6 Conclusion

In this chapter I have introduced the places, which have shaped this thesis. I have suggested that they should be investigated not as different geographical landscapes where solar panels were rolled out, but rather as different emerging geographies, which were enrolled into and shaped by particular socio-material solar assemblages. I have suggested that exploring the different and situated material politics surrounding the use of solar panels in everyday enactments in the two places through a diffractive reading (Barad 2007), would contribute to an understanding of solar panels in use, which would emphasize the contingent, heterogeneous and situated achievement of particular powers. Investigating material dynamics and politics – the capacity of solar assemblages to create particular powers and make possible particular worlds I have suggested provides an alternative to investigating things-in-contexts, by taking into account the vibrant forces of electricity (Bennett 2010).

I have suggested that an ethnographic enquiry with a particular curiosity about non-human devices and forces which are not merely objects of human meaning-making processes, but actors with particularities and propensities of their own, offers a useful method for investigating enactments of domestic technologies in use in order to understand how matter comes to matter in specific ways in different places. I have argued this enables the ethnography to address questions of the multiple powers of solar electricity in a manner, which does not consider social powers separate to material capacity, but considers meaning and matter to be co-emergent.

I have argued that the process of doing ethnography is poorly understood with the notion of 'data collection' and suggested instead to consider processes of doing ethnographic research through the image of the experiment. Considering my own ethnographic practices throughout all stages of the research in this manner has enabled me to consider them as a particular and generative apparatus, which was achieved through collaborative efforts as well as processes of creation rather than discovery.

The methodological choices made in this thesis make it possible to account for the achievement of particular and geographically situated powers. It suggests an analytical approach to the enquiry of energy which does not aim to generate general knowledge about solar electricity as a force or solar energy users as a coherent social group in and of themselves. Instead it considers the situated powers of solar an achievement of an assemblage in which agencies of solar panels and human beings do not exist independently, but come together in everyday enactments in domestic life. Before attending more closely to these enactments in Chapters 5 and 6, it is useful to consider first how the agencies and indeterminacies of solar electricity and the socio-technical assemblages and external circuits they exist as part of, can be made to matter or 'brought to life' in social enquiry. Chapter 4 considers how solar electricity can be made sense of as a vibrant materiality.

4 Vibrant electricities: how do solar panels become powerful?

> "How would political responses to public problems change were we to take seriously the vitality of (nonhuman) bodies?....What difference would it make to the course of energy policy were electricity to be figured not simply as a resource, commodity, or instrumentality but also and more radically as an "Actant"?" (Bennett 2010: viii)

4.1 The achievement of power

This chapter considers what kind of power photovoltaic panels are and become, as they are installed on a rooftop in the north of England or a pole above a house in rural Sri Lanka. It considers particularly what kind of material agency or capacity to do work becomes activated through the respective material-discursive assemblages or arrangements solar panels are installed as part of in the two places. This is an important step in this thesis because it opens up an understanding of exactly what it is that these devices are capable of achieving in everyday life, and how this matters to their everyday enactments.

The chapter wants to achieve 3 things: *Firstly*, it wants to establish that solar power is not a neutral source of energy but a particular power. The chapter seeks to illustrate some of the socio-material enactments involved in knowing and shaping this particular power. In doing so it wants to pay more attention to the material capacity and liveliness of solar electricity, following Jane Bennett's curiosity (above) about how it can be understood as an actant. This foregrounds electricity as power: as a force which has effect on possible new worlds not merely because of the way human beings understand and value and organise it, but because of the power it asserts.

Secondly, it wants to outline an approach to solar panels in which discursive and material forces operate in intra-action. The chapter explains how solar panels only become powerful when connected to both social and material external circuits, and how these arrangements shape their powers. It provides a brief introduction to the kinds of networks of power solar panels in the UK and in rural Sri Lanka are connected to, in order to illustrate how domestic solar panels affect and are affected by these networks. Doing so provides a view of particular situated energies in which the material capacity of energy and the social organisation and meaningfulness of energy are understood as co-emergent. Understanding energy in this manner includes adjusting the question of whether solar panels can be seen to have an *added* social benefit beyond their electricity generation (Dobbyn and Thomas 2005, Keirstead 2007), to a question of how different (and differently powerful) possible energies are *made to matter* in in the process and as an effect of their particular energy generation.

Thirdly, this chapter wants to pave the way for an understanding of enactments of domestic technology where the domestic is not merely a context in which solar power is appropriated, and a place where energy ends up, but a situation where its particular powers (also beyond the household) come together and are shaped: where electricity becomes a particular force. Grid connected solar panels on domestic roofs in the UK challenge the notion of domestic energy users as “end-users”, as flows of electricity do not “end” in the household. A diffractive reading of this situation in relation to so called “stand alone” solar panels in Sri Lanka foregrounds questions of what solar power becomes, following the physics notion that energy cannot be used up or destroyed but rather converted to a different kind of energy.

The chapter proceeds as follows: Section 4.2 briefly reiterates the relevant conceptual and methodological reasoning behind a closer attention to the properties and capacities of flows of energy in general and solar electricity in particular. Section 4.3 then considers solar panels in the UK in four subsection which outline aspects of the material-discursive assemblage involved in the deployment of micro-generation solar in the UK (in section 4.3.1), the manner in which they are installed in domestic households (section 4.3.2), how they act as a particular kind of power (section 4.3.3) and the manner in which solar electricity travels from the household to the wider energy system (section 4.3.4). Section 4.4 continues into a presentation of solar panels in Sri Lanka, also in four subsections by considering firstly the material-discursive arrangements present around their diffusion in rural Sri Lanka (section 4.4.1), the material capacity of stand-alone solar panels in rural Sri Lanka (section 4.4.2) the fluidity of the technical assemblage (section 4.4.3) and finally the connection to related energy technologies and everyday practices (section 4.4.4). The concluding section 4.5 considers how these two enactments of solar panels result in different situated powers.

4.2 Describing solar panels: electricity as electricity

In this chapter I introduce two devices: the Micro-generation Solar PV system, as I encountered it in the north of England and the Solar Home System (SHS) as I encountered it in Sri Lanka in the three provinces Kurunegala, Monaragala and Nuwara-Eliya. I describe what the devices do: what they are for, which parts they include, which other devices they are connected to, which powers they have and how they work. The reasons for doing this relates to my intention to investigate how situated powers come into being in particular places as outlined before, but they relate also to a number of concerns or notions which have been considered in relevant literatures, which it makes sense to reiterate here.

The first one is the notion that solar electricity as a specific fuel has the capacity to create the possibility of a specific kind of material politics. We know about this particularly because of Timothy Mitchell's impressive overview of how oil was historically implicated in the emergence of a certain form of democratic politics, what Mitchell calls our *Carbon Democracy* (Mitchell 2011). We also know from Mitchell that it is important to be specific in what we are talking about and wary of abstraction, because a lot of "stuff" slips out of view so easily: "Ignoring the apparatus of oil production reflects an underlying conception of democracy" (Mitchell 2011: 2) he suggests. What slips in the case of oil and democracy is an understanding of democracy as abstract, as idea or as purely context-independent political model. This is not how Mitchell sees democracy, and not how this thesis sees the manner in which energy is implicated in social life. But as already discussed it is not at all uncommon for matter and democratic politics to be treated as separate, just like it is not uncommon for accounts of oil and the 'oil curse' to be not all that much about oil as oil. Mitchell notes how a slip between oil as material and oil as money results in explanations of it, which

> "Have nothing to do with the ways in which oil is extracted, processed, shipped and consumed, the powers of oil as a concentrated source of energy, or the apparatus that turns this fuel into forms of affluence and power. They treat the oil curse as an affliction only of governments that depend on its income, not of the processes by which a wider world obtains the energy that drives its material and technical life" (Mitchell 2011: 2).

What Mitchell's accounts of oil bring to this account of solar panels and solar electricity is then a concern about them as specific material capacity, as a power, which is not the same as oil. Building on Mitchell's accounts of the connectedness of the properties of oil and the particular forms of power and democracy it co-emerged with historically, this thesis wants to understand how the capacities and properties of solar electricity co-emerge with particular worlds.

A second notion which it is useful to reiterate here is that devices can be meaningfully thought of as indeterminate, and that even technologies which are considered stable technologies may behave differently in different places (Braun and Whatmore 2010). This follows longstanding concerns in STS and related literatures as to how devices travel to different places and what kinds of efforts are involved in them staying the same or changing according to context (Latour 1987, De Laet and Mol 2000, Law and Mol 2001). What these literatures illustrate which is also very much the case for solar panels is that drawing clear boundaries around what they are and what they do is not as straightforward as it may sound. Neither Solar PV systems nor Solar Home Systems are that easy to describe. Or more precisely they are not easy to describe as simply two different kinds of devices in two different places. Because they do not exist as such. Solar Home systems come in different sizes, with different connections and different powers. And the Solar PV systems may consist of 8 solar panels or 16 or a different number, sometimes associated with certain devices and political frameworks, but other times not. They do not all look the same, and they do not all work in the same way. This is not a problem for all accounts of solar PV, but for one which seeks to understand the material capacity of solar in particular, it is a very important point: Solar panels are neither neutral nor general, they work somewhere, sometime. Appreciating this multiplicity and the ways in which the material agency of solar panels *in use* have different powers depending on the various components of the assemblages they are found in, will become very important in the two chapters following from this. So being thorough in the description of these devices is necessary.

The interest of this chapter is therefore not to evaluate whether solar panels do a good enough job wherever they are employed. As Marianne de Laet and Annemarie Mol have famously illustrated, in the case of the Zimbabwe Bush pump, that "the question of whether or not the Bush Pump actually works, as technologies are supposed to, can only rarely be answered with a clear-cut 'yes' or 'no'" (De Laet and Mol 2000: 225). The same question is difficult to answer in relation to both Solar Home Systems and Solar PV systems. Clarity like that is rare and depends on very particular cuts. So rather than asking if solar panels are appropriate technologies for the problems they are employed to alleviate, this chapter wants to investigate what kind of powers they have, how these particular powers come into being.

Focusing on the material agency of devices, which generate solar electricity as well as the agency of the flows of electricity themselves, is in one sense a perfectly obvious place to start an enquiry. That is after all what electricity is: capacity to do something. Beginning to think about notions from the energy literature around 'energy production and consumption' in this way requires a bit of a shift in the way it is considered, a trip maybe back to a physics lesson once upon a time, where the *law of conservation of energy* was spoken about. According to this law, there are some interesting problems with all this focus on production and consumption of energy, as *energy can neither be created nor destroyed*. The fact that energy cannot then be "used up" in physics of course doesn't mean that it cannot be consumed in the social sciences; it is a multiple force like that. But keeping "the physics of it" in mind as a social scientist, might challenge the way energy as usual is approached: It would make you critical for one thing about the idea of energy being wasted. It would make you pause maybe when energy was spoken about in an abstract manner, rather than a particular one. It would make you notice if certain questions weren't asked about, like how much energy and what kind of energy. Having remembered that electricity in physics might be very dangerous for human beings to touch, you might find it peculiar how much effort goes into enabling people to engage with it.

Following this kind of thinking about energy and materiality, solar panels can be introduced as this: A solar panel is a device, which converts the energy of light into electricity. A solar panel consists of a number of solar cells; thin wafers of semiconducting silicon, which absorb photons from sunlight. Within the silicon the photons create electron and hole pairs, which, separated by a built-in electric field, creates a voltage. If there is an external circuit connected this will result in an electric direct current being produced. If the panel is not connected to an external circuit however, no current can circulate, and no electric power can be diffused. The electron-hole pairs simply recombine. In other words, a solar panel on its own has no material force, but is dependent on being connected to an external circuit. Talking about the force of a panel, is necessarily talking about 'a panel connected to a specific external circuit'. Whilst the solar cells, which make up the solar panels, are comparable in Solar Home Systems and Solar PV Systems, the amount of them is different and so are the external circuits, which they are connected to. These things matter for the amount of electricity they have the capacity to generate, and it matters for the kind of power they provide: whether it is direct current which can power certain devices or alternating current which powers others. Capacity in other words is not a simple question of how much power a solar cell can generate. Although this is very important information when you need to match supply and demand, and the kind of information which is often overlooked in social explanations of solar panels, the power of a Solar Home System has cannot be reduced to this, rather it is a question of the power or force of a particular assemblage (Bennett 2005).The question of how these particular assemblages look and work in northern England and rural Sri Lanka, will become clearer in the following section which considers how solar panels come to arrive on rooftops in the UK, and how they operate as part of particular assemblages to acquire particular forces.

4.3 Microgeneration PV in the north of England

Figure 4-1: Solar installation at Peter and Anne's home, April 2011

The sections, which follow below, consider how photovoltaic solar panels become a domestic power in households in the UK and indeed what kind of power that is. When solar panels are installed on households (as seen in figure 4-1), this happens as a result of an assemblage of elements coming together. The following sections consider four elements relevant to the UK: the introduction of the Feed-in Tariff in 2010 (section 4.3.1), the process of installation (4.3.2), the material capacity of UK installations (4.3.3) and the networks of power these are situated within (section 4.3.4).

4.3.1 The Feed-in Tariff: behaviour change and technology push

Solar energy in the UK, or to be more precise, the kind of solar energy that I focus on - grid-tied small-scale micro-generation solar - is a political intervention. The PV systems which form part of my UK based ethnography, were enabled to spread to rooftops around the UK to a large extent because of the Feed-in Tariff (FIT), which was introduced by the Department of Energy and Climate Change in 2010, as a financial incentive to drive uptake of small scale low carbon electricity technologies, funded by a levy on the energy utilities. The objective of the Feed in Tariff system was to

> "…contribute to the UK's 2020 renewable energy target and carbon saving targets through greater take-up of low carbon electricity generation at the small scale and to *achieve a level of public engagement that will engender widespread behavioural change*. This is intended to result in a better understanding of energy use and acceptance of renewable energy technologies"(DECC 2010, my italics).

Under this framing micro-generation solar PV is a "technology-in-order-to" (Verbeek 2005) reduce carbon emissions and to engender behavioural change. Solar Photovoltaic Technology on its own of course does no such thing, but relies on a number of material and political assemblages, as already mentioned. Domestic solar panels are connected to the National Grid. But in order for them to reduce carbon emissions and engender behavioural change, many more connections must be made, some of which are technological, and some of which are political, financial and social. The performances of solar panels in the UK rely not just on meteorological climate, but also on political and economic modes of ordering.

The Feed-in Tariff provided the appropriate mode of ordering for the householders in my ethnography, to invest in the technology:

> *"We like the environment, but not that much… we wouldn't have bought the panels if it didn't make sense financially"* (John, householder, November 2011).

The way that solar panels came to 'make sense financially' was not just through a Feed-in-Tariff, but through a particular Feed-in Tariff. The design of the initial UK FIT model, reflects the view of the Department of Energy and Climate Change in 2009, that on-site use is considered to be the most efficient technically, and more likely to drive positive behavioural change in terms of energy use (DECC, 2009 with Mendonça 2011) In order to encourage on-site use, the FIT payment was initially split into a generation tariff of 41.3p per kWh (2010 level) and an export tariff of 3p per kWh, with generation receiving a far higher return than export.

The FIT however did not merely enable solar panels to become a financially viable opportunity for a particular group of people; it participated in shaping solar electricity and making it calculable on a domestic scale. This situation could be summarised by suggesting that it was a financial apparatus rather than technical capacity of solar which made possible the political and economic enactment that enabled half a million solar PV systems to be installed in the UK between 2010 and 2014. But there are other accounts of how networks of power come into being which offer a different reading of this. Thomas Hughes'(1983) account of the history of electrification in western societies distinguishes between technological inventions that are a result of a specific demand, referred to as a 'market pull' and inventions that are the result of the expanding utilization of an existing technology, a so called "technology push" (Hughes 1983: 20). Empirically of course inventions are rarely either market pulls or technology pushes but a combination of both. But these are interesting concepts to understand solar panels or photovoltaic technology with, or to ask if the situation just described was one of technology being *rolled out* or one of policy being *enrolled*? The purchase of following the latter line of explanation in relation to the concerns of this thesis is that it affords solar panels a different kind of agency: rather than solar panels being seen as passive tools for different politics in different places, Hughes' notions of technology push and "technological momentum" (Hughes 1983), along with Bruno Latour's suggestion that technological innovation has needs and desires (Latour 1996), suggest a different analytical route. Considering the FIT according to these notions shifts focus from questions of whether this particular political instrument would indeed lead to behaviour change, to questions of how "the problems" would have to be defined in order for solar panels to become the appropriate solution.

Returning to the metaphor from the previous section of that powerless unconnected solar panel, it has now become clear that the question of connectivity to external circuits is not merely a question about what solar panels becomes able to affect through becoming part of a particular assemblage, but also how *the needs of solar panels* are met in such an assemblage? In other words the relationship between solar panels and FIT is only a situation of a political need for particularly shaped solar panels, but also the reverse: a technological need for a particularly shaped politics. The following section looks at this more empirically, by considering how particular FIT supported solar panels come to be on domestic roofs in the first place

4.3.2 The PV system moves in: the importance of particular pliers

Figure 4-2: Solar installation at Peter and Anne's home panels and tools

> *" I don't know a thing about how it works. That's the electrician. You can read it, but its all just numbers to me. How it goes up with the angle and the sunshine and all that, I don't know about that. We just fit them"* (roofer, member of installation team, March 2011).

Before PV systems are installed in the UK, a number of calculations are made by both installers and buyers. These provide information on Return on Investment (ROI), which is related to the expected output from the installation. This in turn relates to calculations of positioning of the panels: whether they are due south or south-west etc., what angle the roof is and which the rays of sunlight will hit the panels at, where in the country the roof is, and whether there are any issues with shading, are all components which are put into calculations such as the SAP 2005 (Standard Assessment Procedure), which is the officially recommended calculator in the UK (DEFRA 2005) or PVGIS, a free online calculator which uses Geographical Information System technology to provide calculations for both Europe, Asia and Africa[1]. There is disagreement about which of these two calculators provide the most accurate prediction, however they both provide the buyer with similar kinds of information about expected yield and ROI in relation to a particular dwelling. Neither model factors in what human beings or different appliances do with the electricity after it has been generated, a point I shall return to later.

Once satisfactory predictions and ROI calculations have been produced and a sale has been agreed, installations are generally put up in one day. To better understand what it is that becomes installed in a PV installation, I have arrived at Peter and Anne's house on the morning of the 6th of March 2011.

> (**Research Diary, March 2011**) It is 8am, and the workmen have already arrived. On the lawn are boxes of solar panels (see figure 4-2), perfectly 'black-boxed' with the connection wire being the only sign that something might go on inside them. There are also boxes with rails and screws and a lot of boxes with tools and manuals with schematics and instructions. This particular installation company is new to the business, so a certain amount of effort goes into debating

[1] http://photovoltaic-software.com/pvgis.php

[2] Information about the Standardized Test requirements can be found on the website of the American Society for Testing and Materials (ASTM) http://www.astm.org/Standards/G173.htm

[3] From their website FAQ: http://www.solar-is-future.com/faq-glossary/faq/photovoltaic-technology-and-how-it-works/what-does-kilowatt-peak-

beforehand how best to do things, like how to fasten the panels to the rails. The company, which provides the rails, have a support line, which can help installers with issues, like this. Meanwhile the electrician is busy inside the house. He has discovered that a pin is missing, which is supposed to connect the panels to the electrical system. "*It's just a 10 pence piece of plastic' he explains, but it has to be just that one"* he explains. The little pin is not the only specialised component: My eyes are drawn to a pair of pliers still in their packaging, from a company called *'Galeforce Renewable Energy Systems – Solar Systems Tools'* (see figure 4-3). They are particular crimping pliers, which are made by the company, which also makes the plugs for the inverter, I am told. So you need different tools to install different inverters. The electrician thinks its just a way of making money: *"they say it's a safety thing… to be honest the job itself is not that complicated, but it's all the regulations that come with it"*.

Figure 4-3: Solar installation at Peter and Anne's home, the particular pliers

> After many hours of work, at the end of the day, the installation is complete: the 16 panels are up on the roof, the inverter hidden away in the loft and as the workmen leave, the sun is going down and the little display on the generation meter which they have put above the fuse box as the only way of knowing if the panels are doing anything, is not moving. *"Well, I still don't quite know if all this works"* says Peter with a nervous smile, *"let's just hope it does, it's a lot of money".*

The question of whether this technology works cannot be straightforwardly established by the naked eye. As this example has shown, once the right little pins have been put in and the specialist pliers have crimped the specialist plugs into place, the system is perfectly black-boxed (Latour 1999). As a technology it will generate electricity in hours of sunlight, it will power certain appliances and devices in the household, and it will export electricity to the local grid without Peter or Anne needing to do anything. As a political and financial arrangement it needs a bit more involvement: Peter and Anne will need to report generation figures to their utility in order to receive the economic benefit of the technology. This is the only tangible evidence of the activity of their panels: the numerical representation of electricity flows, which they can read on the generation meter. As far as immediately detectable impact goes, it really is (as the installation worker said) *"just numbers"*. And numbers are indeed a very important element of how solar is made sense of and made accountable in UK households as the following section shows.

4.3.3 Accounting for material capacity: what kind of power?

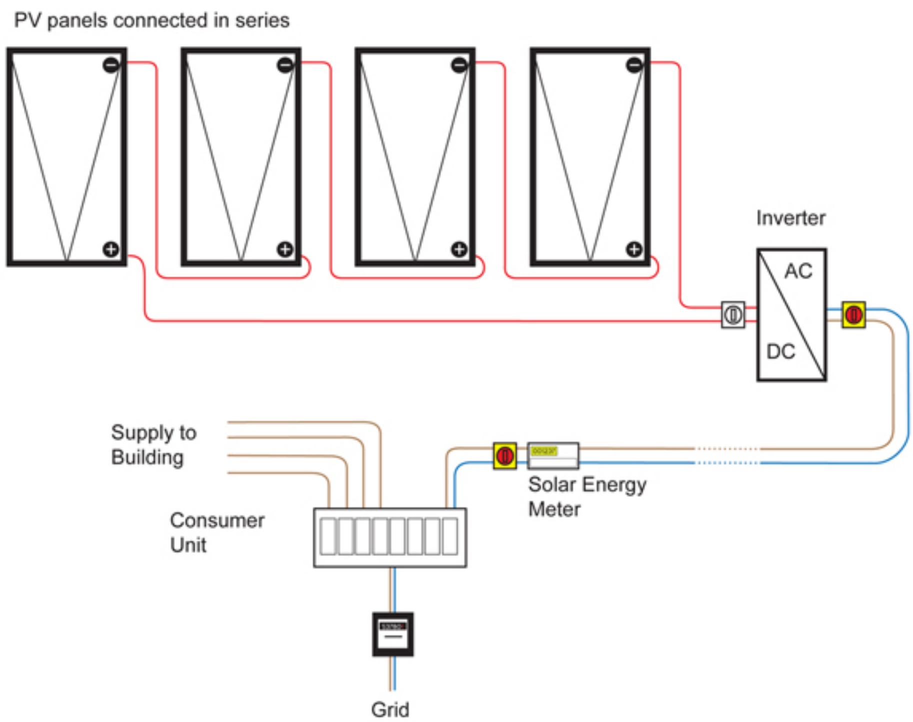

Figure 4-4: PV installation schematic (model from www.viridiansolar.co.uk)

Although Peter and Anne's system does work despite them not quite knowing how, it is useful to investigate this further, in order to better understand exactly what happens in daily life. Appreciating more precisely what kind of material agency a solar PV system has, makes it easier to understand how people and household devices interact with them.

Fig 4.4 shows a typical roof installation in the UK. The array of panels on the roof vary in size between households, with most of them ranging from 2 kWp to 4 kWp. The kWp is very important in the sales transaction: this is how solar power translates into pounds sterling. It is often an unfamiliar term for people buying solar panels. It is a measure of the kilowatt *Peak* of a system, sometimes referred to as nominal power. It is the amount of power the module will produce under optimum radiation. Optimum radiation however, is not a nice sunny day in Leeds, but something that happens in a laboratory. It is arrived at in a standardized test, where panels are subjected to a direct radiation of 1000 watts per m2, under a particular temperature, particular tilting of the panels and so on [2], which is employed by all manufacturers to ensure comparability between different modules.

As panels are installed on roofs this gets more complicated. The sunlight captured by the panels might vary for a number of reasons, which it can be very difficult to determine. The roof might be facing a particular direction, which will impact on when and at what angle irradiance hits it. Irradiance will not just be direct, but also diffuse: so irradiance, which comes not directly from the sun, but has been scattered by molecules and particles in the atmosphere and therefore comes from many directions. There might be issues with shading, and there might be impact from the temperature of the panels. Further on in the system there will be some losses from the distance the flow of

[2] Information about the Standardized Test requirements can be found on the website of the American Society for Testing and Materials (ASTM) http://www.astm.org/Standards/G173.htm

electricity travels between the panels and the utility meter. The kWp in other words provides a platform for considering the prize of the system, rather than precise information about what it will do at any given location at any given time. This is a matter which calculators like the SAP 2005 tries to consider by using particular standards and assumptions, and a matter which is currently being worked on for example at Sheffield Solar.

Calculating and measuring are different enactments. Evaluating exactly what a PV system does once it is installed is difficult, not just for the individual householder. On the Microgen Forum this issue generates a lot of activity amongst PV users. A particular thread on the forum, which deals with the difficulties people are having in finding adequate measurements to compare generation from different installations, includes a request from the users of knowing how Sheffield Solar approaches this issue, which provides a useful insight to just how complex it is to know what solar panels do outside laboratories:

Aldous is a member of the Sheffield Solar staff. He explains in this thread on the Microgen forum, how the Microgen Database investigates actual panel performance, in order to establish just what particular real world panels are capable off:

> *"The efficiency is calculated by first calculating the light energy falling on the panels. This is done by first taking solar data from ground based stations around the UK and calculating the amount falling at each registered installation location. Secondly the amount of this energy which falls onto the inclined plane of the panels is calculated by a complex equation which includes the solar position throughout the year and the proportion of the light which is direct from the sun or diffuse (scattered by the atmosphere and clouds). This figure is light energy per metre squared, so this is scaled up to the size of each installation. Now that we*

know how much energy was received by the panels, we divide the electrical energy yield by this figure. The resultant "efficiency" figure is a proportional figure, so if all energy received were converted to electricity, it would be 100% efficient. In reality this is not possible, and most solar panels are around 10% - 20% efficient. In addition further losses are incurred through the inverter and losses from cables."(Aldous, Sheffield Solar, January 2014)

So the kWp of a system, however accurately calculated and evidenced in a laboratory, is not a straightforward indication of what a system can generate under local conditions on a rooftop somewhere in the north of England. The company Sma Solar Technology, which is a leading manufacturer of inverters and monitoring technology, estimates that the figure in practice is something like 15%-20% lower, not least due to the heating of the solar cells, which makes them less efficient[3]. A solar installer such as Evoenergy however, is more likely to take the kWp figure at face value and tell its customers that *"A PV system with a kWp of 3kW which is working at its maximum capacity (kWp) for one hour will produce 3kWh."*[4]

As the following chapter looks into the effort householders put towards trying to measure and quantify generation from their local installation this becomes important: the difficulties people have in establishing this is not just a problem of inadequate skill or monitoring equipment. Knowing exactly what solar panels can do and actually do at any given time from the point of view of local installation is complex, as the quote above from Aldous at Solar Sheffield indicates.

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[3] From their website FAQ: http://www.solar-is-future.com/faq-glossary/faq/photovoltaic-technology-and-how-it-works/what-does-kilowatt-peak-kwp-actually-mean/index.html

[4] From the website FAQ: http://www.evoenergy.co.uk/ask-the-experts/question/what-is-a-kwp-and-how-does-it-relate-to-kw-and-kwh/

The complexity of accounting for real world capacity and activity of solar systems and the precise powers they relate to is not an everyday problem for the majority of PV users in the UK, who are not directly reliant on solar energy as power, due to the National Grid acting as seamless backup (making it more of an everyday problem for the National Grid as I shall return to later). For the majority of people engaging with PV on a daily basis who were involved in this ethnography, the most important measurement was the total actual generation figure, translated into money. The question of how much nominal power is installed when householders in the UK invest in solar panels has less to do with the amount of power which is needed, or how much electricity a given kWp installation is expected to generate, and more to do with the amount of money they cost. In 2010-2011 a typical PV installation in the UK was in the region between £8000 and £10000, and the performance of solar panels is primarily a matter of concern in relation to this investment. This does not mean the material power of solar electricity is not important for householders, indeed efforts of trying to use this power are the main topic for the following chapter.

These uncertainties relating to potential generation capacity of real world installations put very simply stop at the point of the inverter. Solar panels are connected to an inverter. The inverter converts the Direct Current (DC) coming from the panels into Alternating Current (AC) which is used in the household and which can be exported to the grid. The inverter is most often installed out of sight, such as in the loft or in the garage. Although a crucial part of a grid-tied PV system in the UK, the inverter doesn't need to be accessible to the householder, as it is not assumed to need maintenance and as the information about generation which it produces, is sent to both the generation meter and various portable or internet based monitoring devices. The inverter is the only part of the system, which it is anticipated will need replacing half way through the 20 year Feed-in Tariff period. The price of this replacement is not included in the price of the system. In 2012 when this fieldwork was carried out, the estimated cost was about £1000.

The inverter is connected to a generation meter, which tells the householders how much cumulative electricity has been generated. This number is what they report to their utility on a quarterly basis in order to receive their generation tariff. This number is also used to calculate the export tariff. Systems in the UK mostly do not come with an export meter, which means they do not provide information about how much of the generated electricity is used by the households and how much is exported out to the local grid. I shall return to this in the following chapter, as a number of things happen as a result of there not being an export meter, but in terms of payments, export is deemed and paid at 50% of generation.

Whilst this is the standard installation, most systems also have one or more portable devices connected, which monitor generation and provide information about this through a display on the device itself as well as a connection to a computer. There are a number of different devices on the market, which are sometimes sold as part of the initial installation and sometimes purchased separately by the householder. These different agencies of these devices will become much more important in chapter 5, but in order to further illustrate the complexities around accounting for the impact of the flows of electricity generated by PV systems, particularly as they become translated from kWh to C02, it is useful to include here a conversation which took place in the beginning of my ethnography.

I am visiting Derek and Cathy for the first time about a month after the installation of their 3kWp system in November 2011. Derek is showing me how he uses his SunnyBoy monitor to see what is being generated, which so far is not a lot:

Derek: *"and then there is this: if you press this button you can change the units so it tells you instead how much C02 you have avoided"*

Britta: *"and do you look at that much?"*

Derek*: "well I did for long enough to work out that it was a gimmick!"*

Britta: *"a gimmick?"*

Derek: *well, the only way to avoid emitting carbon is to burn less fossil fuels, right? But how would this thing know if they have switched off Drax or Ferrybridge because of what it is doing? Well of course it doesn't know that, it just uses a clever algorithm to equate kWh to C02. But if I switch all appliances and lights in this household on whilst we're generating, you know and use more than I normally would, that figure is pointless!"*

As Derek has worked out here, the predicted impact on carbon savings from solar electricity as calculated by the monitor rests on the assumption that Derek does not change the way he uses energy: the link is, as he says performed by *a clever algorithm* rather than a material trace. So whilst it can provide him with information of the manner in which translations between electricity and carbon molecules in the atmosphere are made - a very complex issue in itself (Lovell, Bulkeley et al. 2009, Lovell and MacKenzie 2011), it cannot provide a tangible link between Derek's local generation and a directly related reduction in generation elsewhere in the energy system. Just like the SAP and PVGIS calculations mentioned above, this algorithm does not include components for consumption or for what Derek does, and as he has discovered himself this enables him to negate the assumed carbon abatement and render the numbers "useless".

This matters of course, to the overall impact of solar on carbon abatement (Palmer 2013), but does it matter in everyday life? Yes it does. Connecting real world generation to real world impact on carbon or on the flows of electricity in the national grid, or trying to understand what kind of capacity the power they exported had elsewhere, was something which the majority of the PV users in my ethnography grappled with, which the following chapter will illustrate. Householders are not the only ones grappling with this issue. Solar electricity is vibrant and difficult to control also beyond the household, and in order to understand this vibrancy better, it makes sense to briefly look at how it is enacted in the network which solar panels connect to. The following section illustrates how the exported electricity is encountered further along the line, as it travels from domestic power to national power and becomes a matter of concern for the National Grid.

4.3.4 Networks of Power: Solar beyond the household

Once solar electricity "leaves the household" it enters the UK Transmission and Distribution Network. This is often referred to as The National Grid, but consists also of 8 Distribution Network Operators (DNOs), which are the companies, which own and operate the distribution networks, which connect individual dwellings to the transmission network (The National Grid). The both material and financial complexity of flows of electricity in this entire network is beyond the scope of this thesis. A brief visit to the Control Centre of The National Grid however does provide a very useful insight into what kind of agency flows of electricity from domestic solar are as more-than-domestic powers. It provides in particular a useful reminder of what electricity as materiality is, despite the domesticated enactments of it inside the households:

(Research diary 26/2/2015) As you enter the viewing theatre above the control room at the National Grid in Wokingham, the first thing you see is the big video wall which has a graphical representation of the transmission network. It's a thoroughly complex map with colour coded lines, the light blue supergrid line represents 400.000 volts *on the move* the differently colour-coded substations, circuit breakers, isolators, and transformers are fascinating enough in themselves, but when senior forecasting analyst David Lenaghan begins to explain the kind of enactment that goes into running this, and running it safely, the scale of it and the mind-boggling amount of power we are looking at here presents a stark contrast to energy as merely a resource or a commodity. Never mind about just vibrant, this *stuff* is volatile and it is extremely dangerous. It must be kept away from human beings for one thing, but particularly it must be controlled. And controlling flows of power here is not a matter simply of logistics, of knowing where to send how much of it in order to avoid complaints, but of doing so in a manner where nothing blows up, explodes, burns or otherwise malfunctions or breaks at great material and financial cost.

This is the network domestic solar panels are connected to. But what do they do with solar panels here? There is a screen on the video wall, which tells you what the generation mix is. It has gas, coal, nuclear, wind….but not solar. Looking around the control centre there is no trace of it anywhere. *"Its because we can't see it"* explains David. Solar is not connected directly to the transmission network, so rather than being a matter of generation, for the National Grid, solar is enacted as demand. Or absence of a certain portion of demand. *"We know how big a capacity is installed so we can factor that into our predictions, but we can't isolate it from demand"* he explains. The way they 'see' or enact solar here then, is as an issue of frequency: the balance between system demand and total

> generation. The grid has to maintain a frequency of 50 Hz +/- 1%. If demand is greater than generation frequency falls, if generation is greater than demand frequency rises. Solar then is by no means powerless here: the people on the floor in the control room do not take their eyes off the frequency.
>
> On the wall in the viewing theatre is a poster, which shows the demand curve during the time tennis player Andrew Murray, won Wimbledon in 2013. The spikes and drops from when the whole nation goes to put the kettle on in the commercial breaks or immediately after the match provide a nice allegory to the kind of presence solar power currently is here.

What this enactment of solar electricity illustrates in particular is the volatility of solar electricity and the efforts needed to keep people, appliances and indeed the network which channels it safe from its power. The challenge which solar presents to the smooth running of the National Grid is not just about quantities of power, but about temporalities of power: the difficulty with solar is that it is difficult to predict. And whilst this vibrancy of solar is enacted differently at the National Grid than it is in domestic households, related of course to a whole different set of risks and uncertainties, it is performative: it shapes the way people engage with it.

Solar as a force is both vibrant and volatile and achieving useful and knowable but not dangerous power from it involves specific frameworks, which control and account for 'some of the power some of the time'. The efficacy and agency of solar does not stem from one essential quality or source: it never acts alone (Bennett 2005), but rather is ordered in different ways in different places. The force of solar electricity cannot be reduced to the force of a solar panel which it either supported in or prevented from ‘doing its thing’. Solar electricity is a distributed achievement and it is a situated achievement. Solar electricity happens somewhere.

In order to appreciate better how solar electricity is achieved rather than simply distributed in the shape of solar panels, it is useful to look at the manner in which it is assembled and handled in different settings. So in the following section I ‘start over’ in Sri Lanka, following Thomas Hughes’ notions mentioned above by asking not just how solar panels were shaped differently there in order to meet a particular demand or solve a different political problem, but also how particular demands and particular problems were framed in order for solar panels to become a suitable solution.

4.4 The Solar Home System in North Western, Central and Uva provinces

Figure 4-5: Solar Home System installation, Monoragala, Sri Lanka

When Solar panels are installed in off-grid households in rural Sri Lanka like the one in figure 4-5, what is different is not just the installed capacity, or the size of the installation, but also the achievement of a particular technology: solar panels are there for a different reason. The following sections are concerned with the efforts, which went into the achievement of the Solar Home System (SHS) in Sri Lanka. Section 4.4.1 firstly considers the network of international development, which enables solar panels to travel to total villages. Section 4.4.2 then looks closer at the kind of technological assemblage they consist of. Section 4.4.3 shows how this assemblage is a contingent achievement, which is interacted with in everyday life, and section 4.4.4 finally considers the wider networks SHSs are connected to.

4.4.1 Renewable Energy for Rural Economic Development

When Solar Home Systems were enabled to travel throughout rural villages in Sri Lanka, with the help of the Renewable Energy for Rural Economic Development (RERED) project, it was because they were considered suitable devices to help alleviate the problem of lack of electricity in rural villages and

> "improve the quality of rural life by utilizing off-grid renewable energy technologies to bring electricity to remote communities.. To reduce atmospheric carbon emission by removing barriers and reducing implementation costs for renewable energy and removing barriers to energy efficiency" (WB, 2012 p 2).

SHSs were a technology in order to improve quality of life and bring economic development to rural villages. As was the case with solar panels in the UK, as illustrated by the example of Derek's enquiries into the relationship between energy generated and carbon avoided, a number of assumptions about the workings of solar panels, the social force of electricity and the everyday lives of people in rural villages frame this deployment of solar. In order to begin to understand what kind of power is achieved when solar panels arrive in rural villages in Sri Lanka it is useful to look more closely at how the capacity of solar panels is enacted in ways that are different to the way it is enacted in the UK.

The ethnography this thesis is based on was carried out in Sri Lanka from January 2012, a few weeks after the RERED project had ended. The RERED project ran from 2002 –

2011 as a continuation of the previous Energy Services Delivery (ESD) project, which ran from 1997 – 2002, both funded by credit lines from the International Development Association (IDA) of the World Bank, together with grants from the Global Environment Facility (GEF). During the RERED project 110, 575 Solar Home Systems were installed, which together with the 20,953 systems sold during the ESD project amounts to a total of 131,528 Solar Home Systems bought by people in rural Sri Lanka between 1997 and 2011.

The RERED project was administered by the DFCC Bank, which has its headquarters on Galle Road in Colombo, which is where this ethnography began by an interview with project administrator Nalin Karunetileka. During this meeting, the enactment of Solar Home Systems almost immediately changed from being a neutral technology for rural electrification, a means of securing the abstract phenomenon of "access to energy", counted in numbers, where more panels sold equated greater success (more access) which I recognised from the literature I had come to know them through, to deeply troublesome devices which were difficult to control and manage both financially, technically and socially.

SHSs were difficult devices from the beginning of the project: they were too expensive for the market segment the project was trying to sell them to. Lessons learned from the previous ESD project and other World Bank solar projects presented the project with a number of challenges and guidelines in order to set the project up. Lessons learned from the ESD project were mainly about difficulties financing the systems. During the ESD project there were no microfinance institutions involved. People had difficulty getting loans from the existing banks, and vendors did not have sufficient funds to provide finance themselves.

Keeping the price down was therefore very important. Before SHSs could do anything else, they needed to be bought, most often by people who had very little money. It became necessary to create a technical system which could be financed by a 3 year microfinance loan (Laufer and Schafer 2011). In the following section I describe how this was done and what kind of technical system resulted from that. Before that however it is important to consider this situation further in terms of material power of solar home systems, because by following World Bank design principles for successful deployment of technologies such as SHS, namely: getting the prices, the institutions and the contexts right (Wong 2012) decisions were made which framed the most important capacity of an SHS in a way where their material capacity, the amount of power they would be able to deliver was less important. SHSs in Sri Lanka were in other words not sized and designed to deliver a particular amount of energy, rather they were designed primarily to 'get out there', to become products in a marketplace. Similarly to the installation process in the UK amounts of nominal power were important more in relation to cost than in relation to technical performance. The quantities of energy involved here are vastly different with an average UK installation having a nominal power of around 2-3 kilo watt peak a typical installation in Sri Lanka would have between 20 – 40 watt peak. This scalability of PV technology, or the capacity of solar panels to adjust their material capacity according to available finance make them a fluid technology (De Laet and Mol 2000), a property which makes it possible for the technology to enrol such different situations as domestic households in the UK and in Sri Lanka. But it also hides under the notion of 'solar' two very different powers.

As a fluid technology, SHS were very successful in *getting out there*. The RERED project was set up as a private sector project where substantial funds went into exactly this: capacity building for vendors and microfinance institutions, start-up support for new companies, subsidies which went to the vendor rather than the buyer, all of which made the SHS market a very profitable and promising one for vendors to join. As the microfinance institutions came on board, opening the market to a whole new segment of potential buyers, and with the start-up assistance provided by the project, the amount of installers multiplied and reached 15 across the country by the mid-2000s. The number of panels sold was rising rapidly and the project was considered by the World Bank to be a successful model, which it could base its further solar projects on (Miller 2011, Cabraal 2012). Following a particular success criteria, relating to the framing of the technology as directed by the design principles mentioned above, deployment was going well, large numbers of systems were being sold and these numbers were seen as an indicator of success. The project had got the model for successful diffusion of Solar Home Systems in *emerging markets* right (Miller 2011), it had got the SHSs out there.

From the point of view of the project's administration at the DFCC Bank, drawing clear distinctions between success and failure was less straightforward. The story of the solar market in Sri Lanka, told with different inclusions and different exclusions, was a story of boom and bust. In this story sales of Solar Home Systems had been rapidly declining, from 2000 per month in 2005 to 800 per month in 2008 (WB 2012) leading to a situation in 2012 where the solar market had collapsed. Out of the 15 installers at the height of the market, only two were still in business and only one of them made a living exclusively from selling SHSs now in the previously war torn North of the island. It was a messy and distributed enactment of a boom and bust market, rogue traders, malfunctioning panels, defaults and reclaimed systems, and with the politics of grid expansion always looming. Administering solar panels was clearly not business as usual in the DFCC Bank: solar panels might be a fluid technology, but this is not an attribute or a capacity of solar panels themselves but an achievement of an assemblage (Bennett 2005). The contingency, ambiguity and precariousness of this assemblage was all too clear from the point of view of the DFCC Bank on Galle Road.

That Solar Home Systems were indeed troublesome devices was not merely the experience of the DFCC Bank. Previous installers, officials related to the project or to the solar industry shared this experience: what it takes for a SHS to work in a place like Sri Lanka was not at all as straightforward as imagined by the World Bank design principles mentioned above and the notion of "success" it was becoming clear was indeed the result of a contingent selection. Questions of what was external and what was internal to the diffusion and functioning of the technology were overflowing not just on my increasingly messy notepad, but in the manner in which people I spoke to were making sense of it. Most informants would mention the very rapid grid expansion during the period which took the total electrification level from 40% at the time of the ESD project to 83% in 2009, when the solar market began to become increasingly uncertain and the microfinance institutions began pulling out, and further to an estimated electrified household percentage of 94% in 2012 (CEB 2012). Others would mention issues with international solar markets and component prices (predominantly silicon), which were not coming down. Most would attribute some degree of blame on the problematic lack of control of the growing industry of "cowboy-installers". Many blamed the domino effects of events leading to and resulting from microfinance institutions pulling out as the amount of defaults became too great and Solar Home Systems failed to operate well as collateral for the banks, who simply lost too much money, whilst accumulating large numbers of second hand solar home systems, many of which required a lot of work before they could be sold on the second hand market to reclaim just a small part of the losses from defaulted loans. It was a situation of distributed agencies:

> *"you can't really say that it was this or that, it was a number of things and solar might have survived if it was only some of them, but there were just too many things working against solar"* (Herath, installer, March 2012).

I shall return to some of these issues in chapter 6 which looks at experiences of buying SHSs in rural villages, but what is interesting to observe in this mess of distributed agencies is that one source of agency was remarkably absent: the electric power from an SHS. What seemed to have happened was that SHSs had lost their *power to get out there*. There were too many things *working against them* I was told, they had become victims of circumstance.

Circumstance however can be unpacked further. What is particularly interesting for this thesis is to put more analytical emphasis on the power of solar, its power not only to travel to rural destinations but also to power devices and everyday lives once in place there. Understanding what kind of power in order to improve quality of life solar electricity was in Sri Lankan households, what they were capable or not of powering in everyday life, requires a closer look at what SHSs are as a technology.

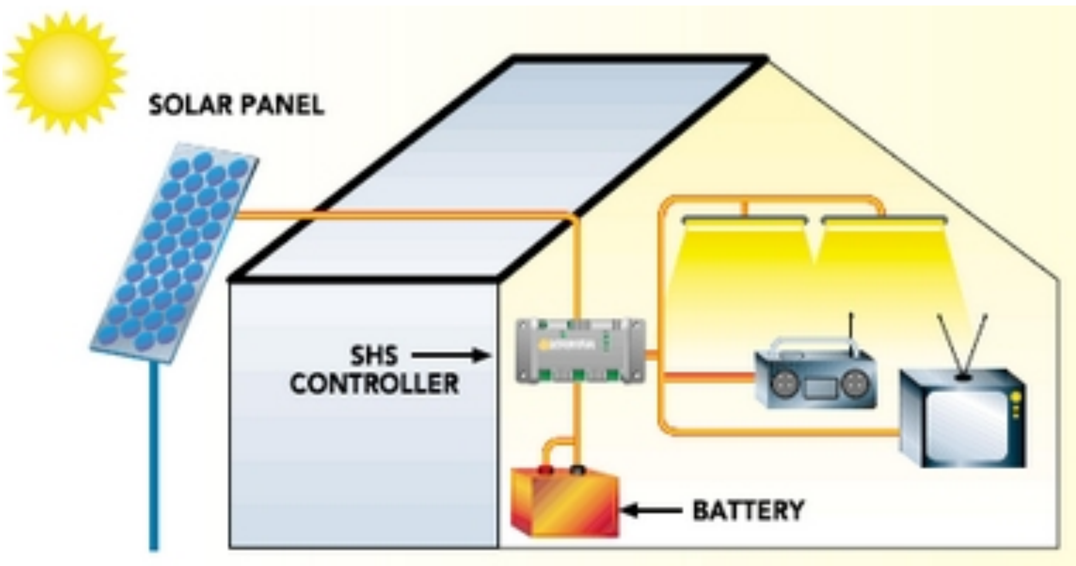

Figure 4-6: Model of typical Solar Home System as used in the RERED project (model from www.zimsolar.co.uk)

The technical specification for Solar Home Systems used in the RERED project explains the basic setup of the systems used in the project as follows:

> "A solar home system (SHS) is intended to provide the user with a convenient means of supplying power for small electrical loads such as lights, a TV set and radio/cassette players. A typical SHS will provide power for dc high efficiency luminaires (fluorescent or Light Emitting Diods (LED)), and 12 Vdc socket outlets for TV or similar appliance for three to five hours a day. Additional 12 Vdc luminaires such as night lamps or DC/AC inverters may be supplied as options. Each SHS shall consist of one or more photovoltaic (PV) modules with an output of 10 Wp or more charging a 12 Volt lead-acid battery, along with related electronic and electrical components and mounting hardware. The SHS must have at least one functional task or area light. The batteries, charge controller, low voltage disconnect and associated components will be located in sturdy enclosure(s)." (RERED 2010)

Figure 4.6 above shows a diagram of such a Solar Home System. In the RERED projects official design, there was a distinction between small systems and large systems. A small system could have a panel with a capacity of 10 – 40 watts peak, and a large system would have a 40 – 60 watts peak panel (very rarely the system would consist of two smaller panels). But as the individual installers were themselves responsible for sourcing the panels and getting the best deal, these guidelines came to include many differently sized panels within this range, although the majority were the smaller ones.

Solar panels generate a Direct Current. In the UK systems are fitted with an inverter, which converts this power into Alternating Current. Inverters for solar systems this size however are neither economically nor technically feasible. Whilst small inverters did indeed exist, as the RERED quote above indicates, they did not work well with these small systems (I shall return to these inverters in chapter 6). So SHSs provide DC power. This is not however the kind of power most household devices run on and which makes these devices useful affordances in everyday life. So whilst SHSs do indeed *"bring electricity to remote communities"* (WB 2012) they bring a very particular kind of power, as Chapter 6 will illustrate further.

The appropriate battery for an SHS from an engineering point of view would have been a deep cycle battery. These are designed to be regularly discharged or to use most of their capacity on a daily basis. But at the beginning of the RERED project these were expensive and worked against efforts of keeping the cost down. As there was a further issue with lack of a supply chain in Sri Lanka, in the official design deep cycle batteries were replaced by car batteries. Car batteries are different technologies to Deep Cycle batteries. Designed to deliver short but high current bursts of power, only discharging a small amount of their capacity, they don't operate well when frequently drained of their total capacity. As this is exactly what happens to them when they are employed to 'stretch out' the daily solar energy stored in them for use during the evening, they often don't last long when they are being used in this manner, which I shall return to in chapter 6. In the different explanations I was given for why a large number of SHSs failed technically, the battery was always mentioned as the main cause. Looking back in 2012 a World Bank advisor to the project told me that:

> *"In hindsight the replacement of the batteries was the wrong decision. People ended up spending as much money on replacing batteries and it made the systems a lot less reliable"* (Anil Cabraal, advisor, February 2012).

In order to protect the battery and the connected appliances, systems were fitted with a charge controller, which using a traffic light system enables users to know how much charge is left in the battery, whilst also protecting it from being overcharged, by simply disconnecting once a certain voltage is reached.

Lastly the systems would come with a number of potential connections for electrical devices such as lightbulbs and direct current black and white TVs. As a small system could include anything from a 10 Wp panel and a 40 Wp panel, the capacity of them would obviously be different, so small systems could include anything from just 2 lightbulbs to 2-3 lightbulbs and a small TV, whilst the bigger systems would power 5-6 lightbulbs and a TV. This difference in panel capacity within the categories of small and large systems contributed to uncertainties in relation to number of devices connected to a particular system, simply because the capacity of one small system could be very different to the capacity of another small system (despite panel sizes appearing to be similar). As a 'technology-in-use' too, SHSs are fluid: Practically all the components involved can be replaced. Replacements sometimes happened before the systems were even installed, in the negotiations between buyer and seller, but more often they would happen after a period of time, either as efforts of maintenance and repair or as ambiguous improvements to the system made by the owner. Unlike the PV installations in the UK, SHSs were not black boxes, they were contingent assemblages.

4.4.2 The Solar Home System as contingent technical assemblage.

Figure 4-7: Battery connected directly to loads without a charge controller

We know from the STS literature, and have seen already in this chapter that fluid technologies might be better at travelling to and operating in out of the way places than less fluid ones (De Laet and Mol 2000, Mol and Law 2001). However as will become clear in this section, this fluidity might not be a straightforward affordance when looked at in everyday life over a period of time.

SHSs in rural Sri Lanka did not hold their shape well, but operated with or without certain components from the model shown in previous section. A component, which was frequently taken out of the system, was the charge controller (see figure 4-7). There were a number of reasons for this. Sometimes it had stopped working and the lack of maintenance and repair infrastructure left it up to the owner to come up with a solution. Other times it was working, but considered to do the wrong kind of work. The charge controller did a job some users had found to be problematic: it prevented the battery from being charged to the very top of its capacity. Not having the charge controller would therefore give them a little bit more power in the short run. Given the small amount of power a SHS provides a further group of users felt that the traffic light information display was taking up electricity they could themselves put to better use. Being a fluid technology, the SHS would continue to work without the charge controller.

But an SHS is not a bush pump, and technological fluidity was not just something, which enabled the device to go on working despite the malfunction of a component. Without the charge controller, the SHS worked *differently*. And this difference was a source of controversy between SHS owners on the one hand and installers and RERED officials on the other. Analytically, for the researcher, the controversy was also an insight into how different enactments of SHSs co-existed and occasionally came into conflict (Mol 2002). The disconnection of the charge controller was understood by the people I spoke to in the solar industry as a compounding factor on the short lives of some batteries. People didn't realise what they were doing, it was believed.

> "*Some people took the charge controllers out. But the charge controller was there to help make sure that they didn't overuse the battery, so without it they overused the battery and then it didn't last very long. So they thought they were being clever but the batteries died like that*" (Installer, Monoragela, May 2012).

The shortening of battery life-time was one of the main reasons for system failure and as this installer pointed out, overcharging a lead-acid car battery is risky business which can become a serious hazard[5]. This was a classic case of people who didn't understand the consequences misusing the technology, or using it in the wrong way, I was told.

The DIY solar users I spoke to saw it differently:

> *"I know that* [that it puts more strain on the battery]*, but it gives you more light and TV like that. We spent a lot of money on this but it only gives us a little power. You can always buy a new battery"* (Rukshan, householder, March 2012).

What is an enactment of 'not understanding the technology' for this installer, is an enactment of 'improving a capacity based on experiential knowledge of what it does or does not do' for this user. He did not need a battery to last a lifetime, he needed more power.

Even more fluid than the charge controller, was the amount of loads, which could be connected to the systems. An installer I spoke to explained it like this:

> *"There was a small system and a big system. The small system only had 2-3 lights. People wanted more lights and TV and music, but they could only afford the small system. So they bought the small system and then they connected more lights and TV themselves. Later they called and said the system we had sold them didn't work*" (Installer, Maho, April 2012).

[5] (Other than the battery simply dying from being overcharged what can happen is that it will boil the sulphuric acid and distilled water mix. This will produce heat which may cause the casing to melt or swell, allowing for flammable hydrogen to seep out. Introduced to oxygen this can become a serious hazard, as a small electrical spark can cause the battery to explode and send plastic and lead shrapnel flying as well as caustic sulphuric acid spray

These adjustments to systems were again well known by the RERED administration and the solar industry and were framed as misuse. They explained to me how this was one of the main reasons why (what would have otherwise been perfectly good technological) systems failed: because people tinkered with them so they stopped working.

This explanation of the uninformed, tinkering (the word *"clever"* was often used) solar user causing the technology to malfunction was dominant: it was the fault of the uneducated user. I put this suggestion to a solar user whom I had come to know well, which clearly made him frustrated and angry with me for suggesting that the increased cost in battery replacements was due to the way he had tinkered with his system:

> *"You don't understand! When you buy the solar it can't do much. It costs a lot of money, but you only get a few lights and very little time to use the stereo and the TV. So if we just had the two lights then they are expensive lights. These people you talk to they think we are not very clever, but they live in the town, they have the line. They don't know what it is like in the village, and they don't know what solar does*" (Janeka, householder, April 2012).

Contrary to the account I was given at the DFCC Bank in Colombo, this man talks about the capacity of the system: if it works well as a technology, if it delivers the amount of electricity it was built to deliver, an SHS powers a few 'very expensive lights' and a very limited range of devices for a short period of time. Even if it works perfectly well, which was not frequently the case for very long, with a little bit of electricity you can only do a little.

So Solar Home Systems, which work as imagined in the technical specifications, might not be make them appropriate technologies in their situations of use. No amount of fluidity in the system could change the fact that it only has the capacity to provide a very small amount of power. If the work, which it is capable of, doing, is not enough or is not the right kind of work, does it then work well? The answer to this question depends on very carefully drawing lines between what is internal and what is external to the calculation. Or put in a more colloquial way: it depends who you ask.

4.4.3 Networks of power 2: how Solar does not stand-alone

Figure 4-8: Solar installer and battery shop, Maho

In order to understand the properties and capacities of solar panels in rural Sri Lanka, it is useful to consider both what kind of power they deliver and what kind of power they are connected to. Contrary to the situation in the UK, the watt peak capacity a panel had or the amount of electricity it generated was not easily established. The process of buying solar involved taking up a loan and buyers would be presented with an outline of required instalments in order to estimate how long the loan repayment would take. They were not however given the kind of calculations users in the UK were given in order to estimate how much power the panels would generate over a certain period of time, there was no equivalent of the SAP 2005 prediction enacted here, just like there were no monitoring devices which gave users the opportunity to monitor their actual generation figures against weather-data or to establish generation patterns etc. Solar panels were not rendered accountable in those kinds of numbers. Knowing what individual system performance was and how this changed for example, as the battery got older was not possible.

Coming to know what solar did in everyday life was instead a matter of developing an experiential knowledge of the capacity and a familiarity with its capacities: an enactment of trial and error. The important component for this, the one which people engaged with and related their energy generation to, was the battery: the most vulnerable and most important part of the Solar Home System. This is where I was always taken first, when I arrived at a new household, asking about solar: to the battery. Solar electricity generated by the solar panel was stored in the battery. Reading the battery diffractively up against the National Grid in the UK enables a number of insights into what kind of force SHSs in Sri Lanka provided. Batteries are of course a completely different technology: it stores power, which the National Grid does not. But it performs a similar support to solar electricity: it counters the problematic (when employed in domestic settings) property of solar electricity that it is generated predominantly at times of day when it is not needed in the household. This was also the case in Sri Lanka.

Knowledge practices in relation to finding out how much power was available then were practices of switching devices on and seeing how long they would work or connecting more devices and seeing whether they would still work. It was a process of experimentation. After a period of time users would come to know roughly the amount of power they had. Here is an important difference in enactments of electricity, or what kind of force electricity comes to be in the two different uses in the UK and in Sri Lanka. Solar electricity here was not a pattern of generation, it was not an intangible flow of electrons through wires in the house; it was a tangible portion of power, located inside a battery. People knew exactly what it powered and when there was no more power left. (Chapter 6 will look at these enactments of knowing power and using power in more detail).

Batteries unfortunately do not last as long as solar panels. According to a survey carried out on behalf of the RERED project, the weighted average life time of a first battery was calculated to be 30.4 months (Mawatha 2005). This fits reasonable well with my ethnographic fieldwork findings, where people would explain having to replace batteries every 1-3 years depending on usage and quality (which brand, new or refurbished) of the battery they could afford to buy. At the time of my visit to Sri Lanka the price of a battery was in the region of 10.000 rupees, which was a large amount for the majority of SHS households visited, up to a full month's income for some of the poorest and most rural families visited.

The replacement of the first battery would most often happen before the systems were fully paid off which often led to periods of the SHSs being out of use, or not providing sufficient power to be used sensibly in the household (providing intermittent, flickering lights only for example), because it was not currently possible for the household to afford a new battery. The different states different batteries could be in makes it difficult to say how much power SHSs were able to generate. Whilst a new battery was generally capable of storing electricity for 4 hours on a full charge, this was only the capacity for a while. A year or two after installation the solar panel would still be capable of providing enough electricity for this level of charge, but the batteries would most often not be able to store it. Ascertaining how much power different households had at their disposal after given periods of usage was not possible, just like knowing what losses were incurred from poor quality and often faulty wiring and inefficient appliances was impossible to establish. Knowing solar electricity as a portion of power which remains in the house until it is "used up" is not having an any more stable affordance, or does not make it any easier to rely on it as power.

Because solar electricity was an uncertain and fluctuating source of power in many ways, other sources of power were needed which took on again a role not entirely dissimilar to that of the National Grid in the UK: solar electricity was part of an energy mix, also in Sri Lanka. Solar electricity being off-grid was not the same as it being "stand alone". There is an obvious difference in scale between PV systems and SHSs, but in everyday lives it was not just an issue of *how much* power that prevented solar electricity from being a stand-alone source of energy in either location, it was an issue of *what kind*. Solar is an intermittent kind of power, and this property does not change as it is scaled.

A number of back-up powers were necessary for the everyday workings of SHSs. The majority of SHS users already had many years of experience using car batteries to power devices in their houses, so during times of poor generation they would revert back to those: disconnect the battery and take it to the nearest charging shop in the village or nearest town. Similarly people would always have kerosene and battery-operated torches in their houses for back up. In relation to the schematic of the SHS in section 4.4.3 an SHS-in-use in rural Sri Lanka provides a poor match to this assemblage, not just because of adjustments being made to it, but also because of its reliance on external powers. SHSs very rarely worked as isolated systems, but in connection with other complementing systems. Where Fig 4.4 of the PV system in the UK shows a connection to the Grid (p. 86), it would have been more representative of real life employment if the

SHS model had shown a connection to these other powers. SHSs did not replace the kerosene lamp and the system of light provision, which came with it, it co-existed with it. It worked as a particular everyday affordance because they were still there. In order to understand the material capacity of SHSs, this is an important detail: they cannot be relied on as a standalone power. This is not a question of quantity (even a 40 watt solar panel can power a number of useful loads) but a lack of constancy: people did not only need light on sunny days.

To re-iterate the intention in the technical specification from the RERED project referred to above to power "small electrical loads such as lights, a TV set and radio/cassette players'", these are not just examples of small loads taken from a wider group of equally appropriate loads, they are particular loads. They are material-discursive loads. Solar electricity in other words is not immutable: its material capacity is not independent of the particular loads it powers.

4.5 Situated powers: making matter matter

Anthropologist Clifford Geertz has suggested that "One of the most significant facts about us may finally be that we all begin with the natural equipment to live a thousand kinds of life but end in the end having lived only one" (Geertz 1973). When he wrote that of course, his curiosity lay with the human being and the manner in which cultures shape human beings. And it is perhaps doubtful whether he would appreciate this sentence being called to work in an enquiry about solar panels. But it provides I think a good allegory to what has been the subject of this chapter: the material-discursive emergence of particular situated powers and their situated matters of concern.

Solar photovoltaic technology provides a powerful way of generating electricity. Its scalability makes it amenable to a number of different uses in different places. In this chapter I have focused on two political enactments of solar panels: two different ways of bringing solar panels and particular energy challenges into relationship with each other, resulting in two different ways in which solar panels have been connected to particular external circuits in particular places. In this manner the chapter has begun questioning what the specific relationship is between different enactments of solar panels as technologies-in-order-to (Verbeek 2005) or the political and social job they are employed to do in different places, and the way they are sized, designed, connected and "wired up" materially.

This chapter has thus shown two different ways of taming or tuning (Pickering 1995) the vibrancy, liveliness and particular properties of solar electricity, whilst also showing how the particular vibrancy and material properties of solar panels have shaped and defined different understandings of the job they were enrolled to do, and the human and environmental needs and matters of concern which made them the appropriate tool for the task. The reading of the PV system in the UK with its connection to the National Grid has highlighted how solar electricity is lively and difficult to predict and contain. It has also shown how it becomes a particular flow of electricity and how it is volatile and dangerous unless subject to different kinds of husbandry at different places. The reading of SHSs has highlighted how solar electricity in this particular circuit becomes a *particular portion of power*, but that the size of this portion is variable and difficult to know. It has also shown that the limitations of its capacity were not solely a question of quantity of electricity, but also of kind and of timing.

I have suggested considering these enactments of solar panels material-discursive: they have shaped the properties of solar panels into specific situated capacities enabling particular uses, effects and connections whilst preventing others. Situated solar powers as I have encountered them empirically in the UK and Sri Lanka I have argued are the result of *one* possible way of ordering and reacting to the specific properties of solar electricity generation and technology: they are contingent achievements. I suggest that this understanding of solar panels in use offers an adjustment to the way in which we understand how technologies such as solar panels can come to do 'more-than-technical' work or have 'added benefits' in some situations more than in others, by prompting the question of what kind of power is appropriate for a particularly framed set of challenges. This involves in particular an understanding of electricity where it is not equal: where its degree of usefulness is not just determined by quantity but also quality and temporality: a Wh which is available between 1pm and 2pm is not the same affordance as a Wh which is available between 7pm and 8pm.

Solar electricity then is inadequately understood without attending firstly to questions of what kind of power it is, which loads it powers, which other powers it co-exists with and what kind of wider assemblages it acts with. This it what makes them situated powers or capacities to do specific kinds of work. Considering the material capacity of solar panels an achievement of the setting or of particular external circuits, rather than as a neutral attribute, thus sets out an analytical route where the material capacity of solar panels can be investigated not so much as a latent potential which is either realised or prevented in inter-action with human beings in different contexts, but rather as something which emerges in particular material-discursive intra-action. This affords an analytical situation where solar panels are not passive victims of circumstances: of human beings interpreting and using them in unfortunate ways for example, but indeterminate devices which have, to speak with Geertz above, *the equipment to live a thousand different lives*.

In the following two chapters I consider the enactments and achievements of situated powers in everyday life. In chapter 5 I attend to enactments of Rooftop mounted PV systems in domestic households in the UK. In chapter 6 I attend to enactments of Solar Home Systems in domestic households in Sri Lanka. Having established in this chapter the situated powers of the two devices, I attend more closely to how these are lived with in the particular setting which is the domestic household, and how they become powerful and useful in ordering both matter and meaning together (Barad 2007).

5 Thrift, temporality and lunchtime clouds – ambiguous enactments of microgeneration solar PV in the UK

5.1 Encountering clouds

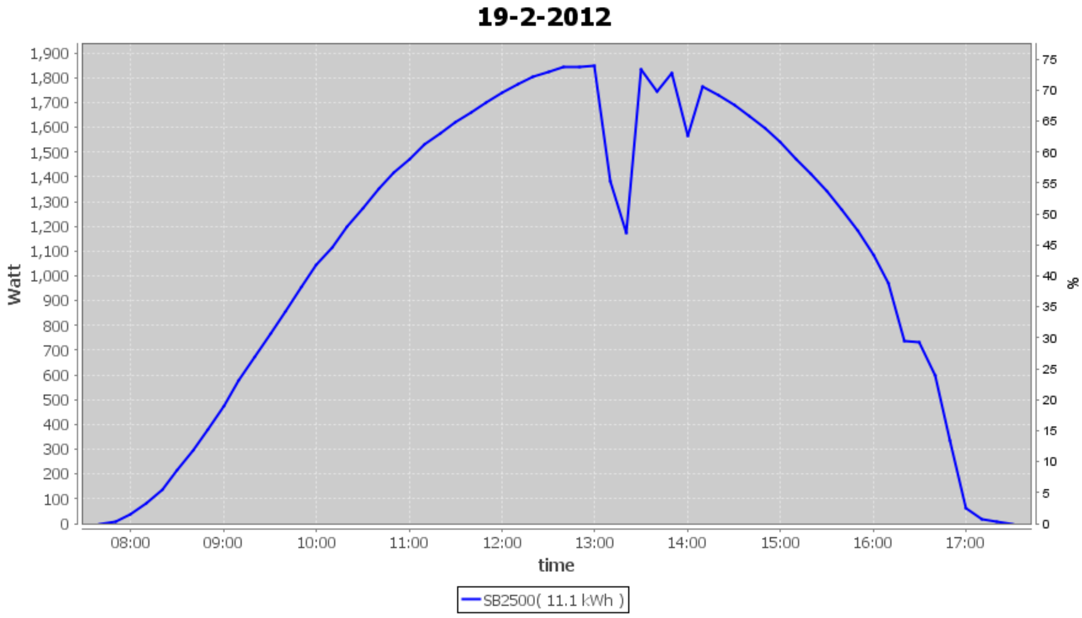

Figure 5-1: "The lunchtime cloud". Graph showing solar generation on the 19/2/2012, produced by householder Simon

Simon has a Sunnyboy PV monitor. Since having solar panels installed, monitoring their use has become a hobby. Simon's panels are linked up to a network of monitors and computers and websites containing information about expected yield, weather, even generation figures for other panels in different countries, to compare and contrast. He spends a lot of time monitoring at particular intervals, entering data into spread sheets, running the data through computer programs, making and customising charts (see figure 5-1), comparing actual generation with expected generation and even comparing generation data with consumption data. His knowledge of exactly what his panels do is extremely detailed. We are looking at graphs Simon's monitoring software has made, based on daily generation figures (Simon, householder, October 2013):

> Britta*: So in the middle, there, is that a cloud?*
>
> Simon: *Yes it is, I've noticed this. Consistently we get sunshine, and that was at about 11.30, and then at lunchtime we get a bit of cloud, and the cloud goes away again! So just when you would like peak power, when we're going to have lunch, there's cloud (we both laugh). It's weird. So actually we're better off putting electrical items on just before lunch and just after lunch, and forgetting all about the lunchtime period. I guess if I looked at August it might be a similar thing. Yes I noticed this myself a few weeks ago, that there is this oddity. (Simon searches for another graph).*
>
> Britta: *(looking at graph) oh yes, there it is again, not as significant but definitely a lunchtime cloud!*
>
> Simon*: There is a definite, consistent… just when you think 'we'll put some beans on toast on' or you want to put the toaster or hob on. Ok, all it's done on this one is drop from 1,1 units till 1. We'll be generating more power than what we're using, so that all right. I've had some great times with these charts! (He laughs)*

In this chapter I investigate the everyday achievement of a situated power. I question how solar power emerges as a particular material-discursive force through an investigation of how solar panels are enacted and made to matter in everyday life in the north of England. I look firstly at the patterns of power solar panels generate and consider the importance of their particular temporality in relation to the ways in which people use electricity in their homes. Secondly I look closer at the way solar panels and the electricity they generate are shaped and made to matter through efforts of keeping track of and making use of particular flows of solar electricity in the home. I then introduce the devices, appliances and specific energy uses mostly affected by solar electricity before considering the particular kinds of changes, which emerged. By applying the conceptualisation suggested in the previous chapter of solar power as a contingent achievement of the setting, I suggest that a greater curiosity about what kind of material power emerges in these situated enactments of solar provides an alternative account of how changes to domestic electricity uses may or may not emerge with the introduction of solar panels to the household. I finally consider how this understanding of situated power can contribute to understandings of energy use in which the household is not located at the "end of the pipe".

5.2 Patterns of power

When and how much do solar panels in the north of England generate electricity? Although there is variability due to geographical location, panel orientation etc., it is generally true that solar panels in the UK generate the most power mid-day and during the summer. Although the people occupying the houses where these flows happen can know the patterns of power, making use of that power is less than straightforward. In the previous chapter I have illustrated already how the Feed-in Tariff was designed to encourage on-site usage. This chapter will illustrate how this is just one of a number of reasons for why the householders involved in this research would try and modify their electricity consumption patterns to match the generation patterns of their solar PV systems, but first it is important to look more closely at what these patterns may look like on a domestic basis. The following 4 graphs from the same 2,5 kWp installation, provide insight into the patterns of local generation:

A sunny day without much cloud cover will look something like figure 5-2, which shows a nice bell curve with a sustained period of relatively stable good generation between late morning and late afternoon.

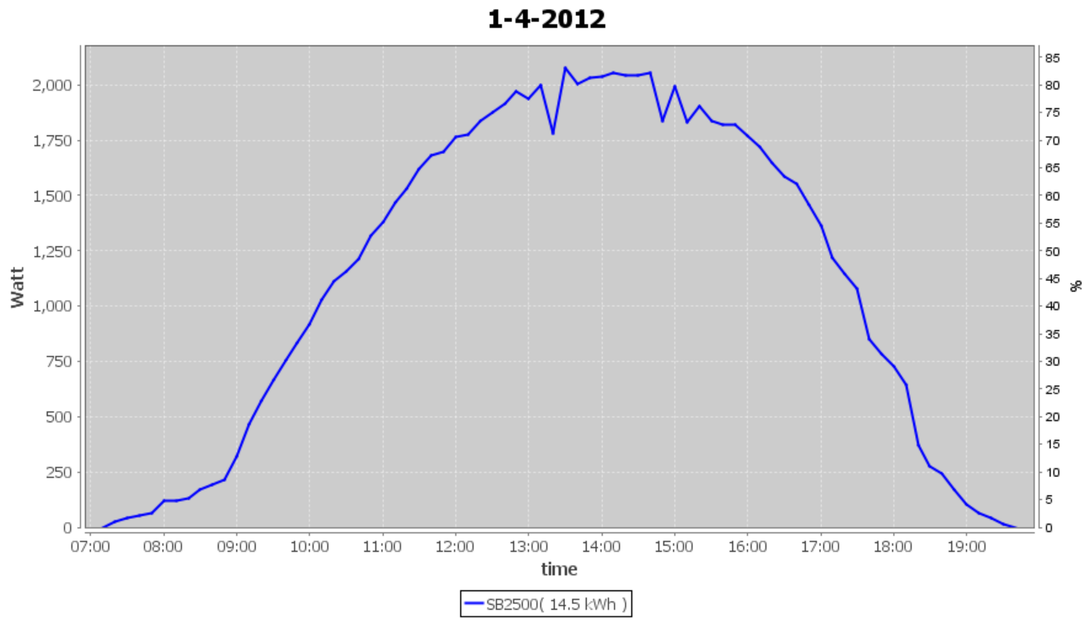

Figure 5-2: Domestic solar generation achieved by Simon's installation on 1/4/2012

However as clouds are a very frequently occurring phenomenon in the UK, often daily generation will look more like figure 5-3, where the output is heavily influenced by intermittent cloud cover, with unpredictable and unstable levels of output during the whole day.

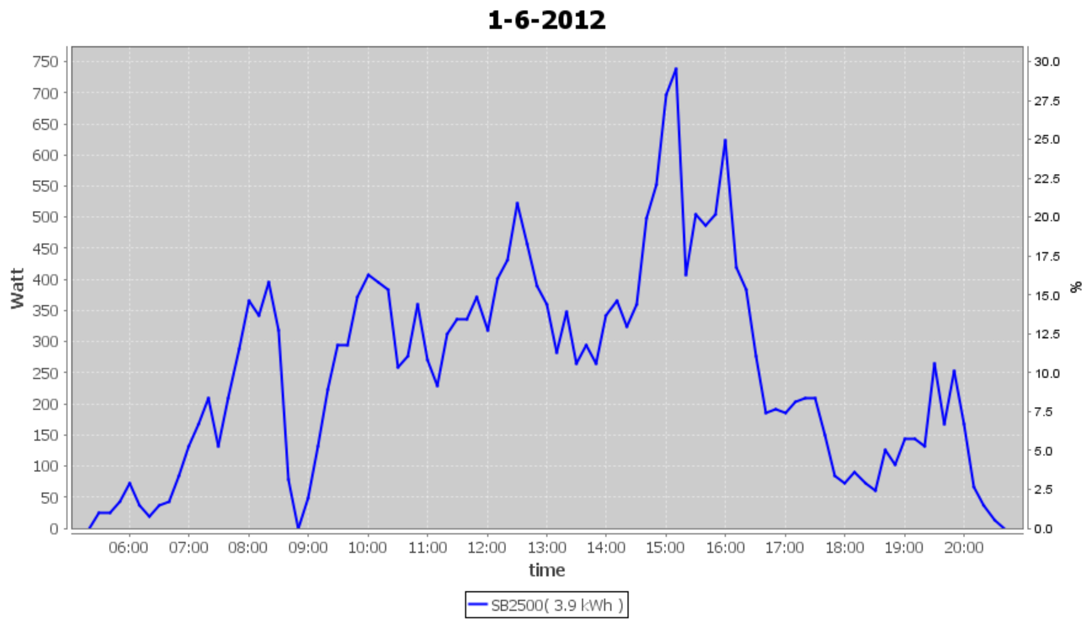

Figure 5-3: Domestic solar generation achieved by Simon's installation on 1/6/2012

Looking at daily generation figures over a month, gives an idea of how differences in weather, particularly cloud cover impact on generation, as seen in figure 5-4 below:

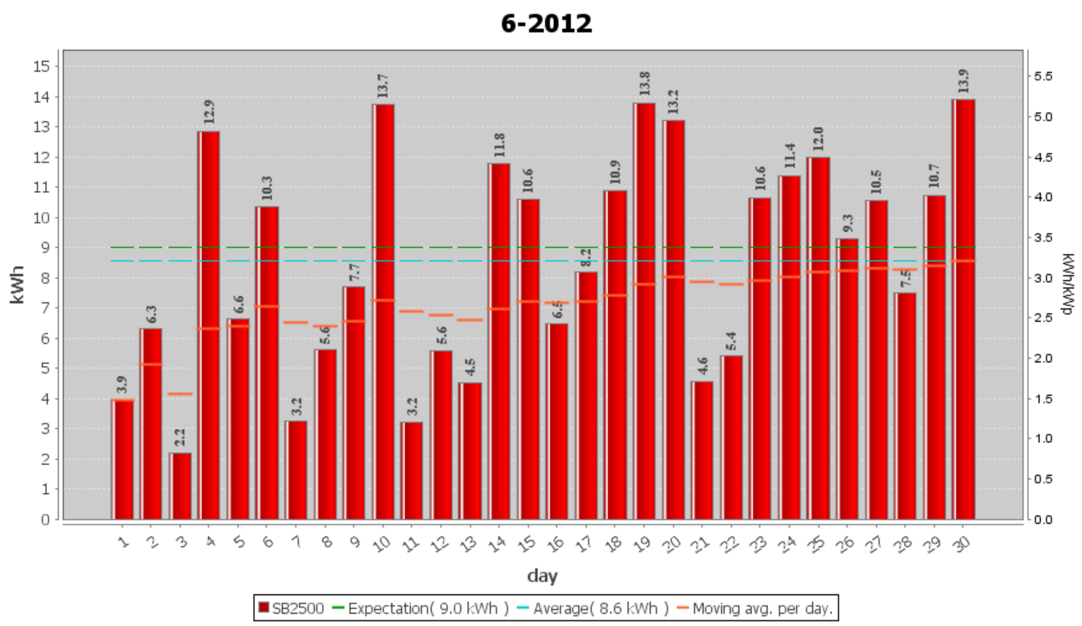

Figure 5-4: Domestic solar generation achieved by Simon's installation during June 2012

And lastly of course the seasonal amount of sunlight during a year, also causes a particular generation pattern, with great differences in amount of electricity generated at different times of year, as seen in figure 5-5:

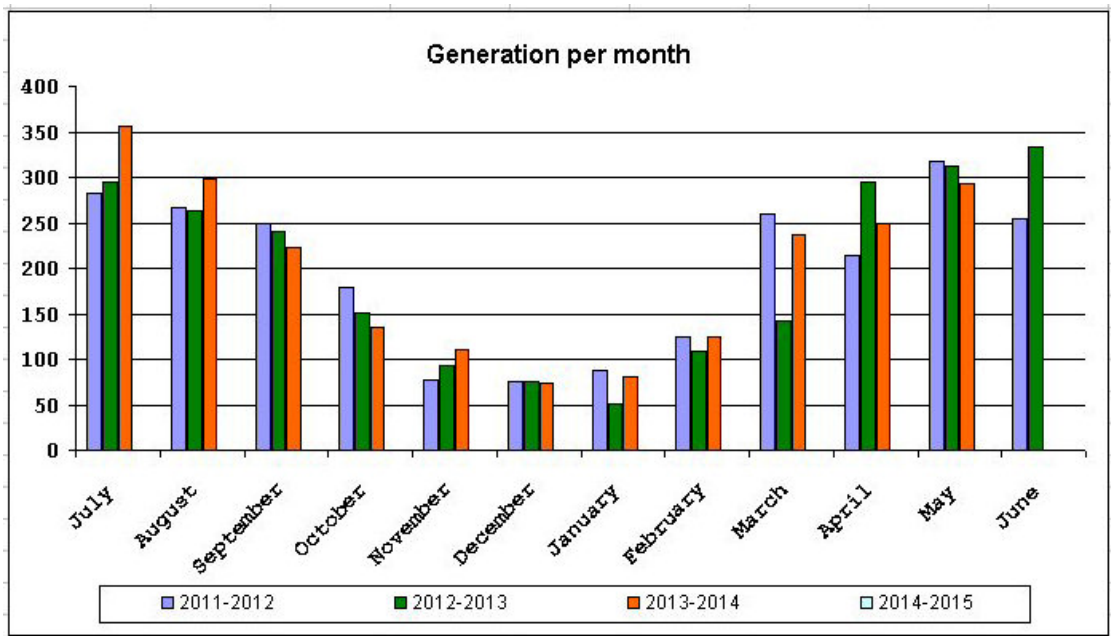

Figure 5-5: Domestic solar generation achieved by Simon's installation annually during the years 2011-2015

As can be seen from these graphs, PV electricity has a very different material presence in the household to grid electricity. This is made up for by the connection to the grid, which seamlessly ensures continual power at all times, and doesn't therefore pose any everyday challenges to the running of devices inside the house. Average household consumption of course is based on a different kind of fuel, with different temporal characteristics: electricity, which comes from the grid, does not have temporal differences as far as the domestic user is concerned. Domestic energy consumption is shaped by this achievement of constant availability which enables it to be consumed not according to availability, but rather according to wider social, structural and cultural practices and patterns (Shove 2003). Domestic energy consumption in the UK, is dominated by an evening peak between 5pm and 10pm, with the 6pm till 8pm period being more than 3 times the average base load (Owen 2012, Palmer, Terry et al. 2013). The graph below showing aggregate electricity consumption in the UK[6] gives a good indication of when residential electricity is typically being used in the UK on a daily basis, compared to commercial demand.

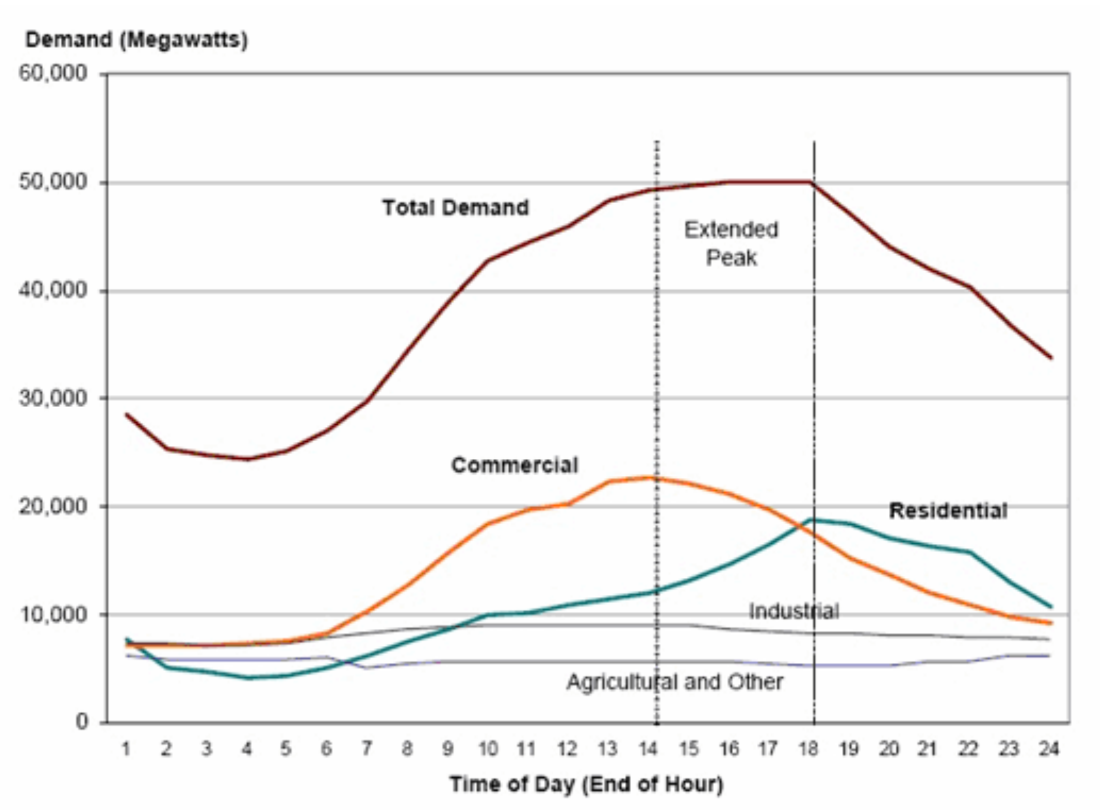

Figure 5-6: Average electricity demand curves UK (model from The National Grid visitors centre)

Comparing this pattern to the two graphs above showing daily solar electricity generation begins to illustrate what kind of challenge solar power poses not merely for

6 http://www.mpoweruk.com/electricity_demand.htm

the domestic user, but for the UK energy system more widely: the manner in which PV electricity as a material force is present for the typical UK household to use, provides not only a poor match to average consumption patterns but due to its variability, not least seasonally, a somewhat unstable basis for a transition to a particular solar powered energy use routine or habit. Although this does not cause a significant problem for the running of devices in the majority of households in this part of the world (which rely on back up electricity from the grid) it does have consequences both for the grid and for the potential carbon abatement. In my ethnography it also had consequences for the manner in which PV electricity was made to matter in everyday life, as the following section explores further.

5.3 Power in numbers: experiential knowledges of solar

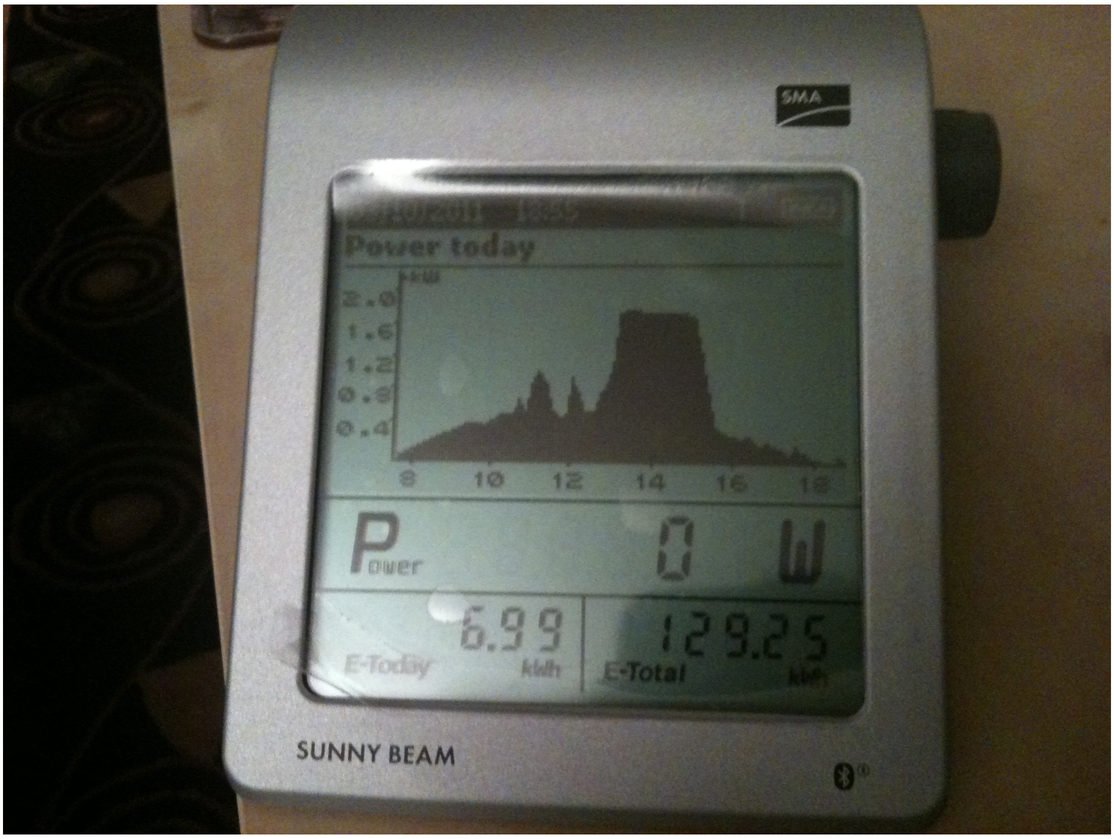

Figure 5-7: Sunnyboy monitor display showing accumulated daily generation at household in Leeds

Domestic solar panels can be seen as an example of what Noortje Marres refers to as "environmental engagement made easy" (Marres 2011): they enable people to act on the environment in a particular way without requiring them to put in any effort to change. In order for solar panels to generate electricity for use in the household and beyond, householders do not need to do anything. But one thing is technological design and intention; another thing is investing between £8000 and £16000 on a PV installation and then just leaving it to its own devices. The PV users I met knew that their systems would work as a Fit and Forget technology'. But they did not forget, rather the first year of living with solar panels involved a great deal of effort put towards getting to know and use solar electricity in a manner which made the most of both its financial and environmental potential. Making the most of solar is a challenge of using it in the house when it is being generated. In order for this to happen new practices of using up daytime electricity have to be established. Doing this in a less than careful manner however, could result in increased energy consumption. So in order not to use more electricity than you are generating, practices of keeping track of generation and consumption levels are also required. Keeping track of PV electricity generation patterns was part of living with PV in all the households I came to know, although to greater or lesser extent. The reasons for doing so were not always clear cut as seen in the introduction to this chapter, but the main reason people would try and make visible the flows of electricity coming from their panels, was the Feed-in-Tariff which made solar panels in these houses not just electricity generating devices, but also money making devices. All households included in this research received the level of FIT initially set in 2010, which was then 41,3 pence for every kWh generated, whether this was used in the household or not. As well as that they received a 3 pence export tariff deemed at 50% of generation. This gave them a financial incentive for onsite usage, but was not the only reason why people explained they were trying to use electricity at home, as this chapter will explore further. But importantly it provided a framework for keeping track of electricity as money.

There are no clear guidelines in the solar industry regarding monitoring devices. Some installations involve only a generation meter; others come with a mobile monitor (see figure 5-7), often with the ability to upload data to a computer to enable further calculation and exploration of the data. These monitoring devices shape PV electricity and render it accountable as a 'technology that makes money'. They also provide assurance that the system is actually doing what it is expected to. As I visit Matt a year after they have had their solar panels installed, he has produced a number of graphs as shown in figure 5-8 to illustrate his generation and explains:

January 2012		
	SB 2500HF-30	
	2120086785	
time	E-Today	
DD/MM/YYYY	kWh	
01/01/2012	0.357	
02/01/2012	1.868	
03/01/2012	0.792	
04/01/2012	0.453	
05/01/2012	1.644	
06/01/2012	1.484	
07/01/2012	2.122	
08/01/2012	1.152	
09/01/2012	0.602	
10/01/2012	1.717	
11/01/2012	0.835	
12/01/2012	2.08	
13/01/2012	1.877	
14/01/2012	2.298	
15/01/2012	1.124	
16/01/2012	2.366	
17/01/2012	1.805	
18/01/2012	1.722	
19/01/2012	2.518	
20/01/2012	0.688	
21/01/2012	1.068	
22/01/2012	2.857	
23/01/2012	1.579	
24/01/2012	0.436	
25/01/2012	1.073	
26/01/2012	2.385	
27/01/2012	1.653	
28/01/2012	2.167	
29/01/2012	0.961	
30/01/2012	2.027	
31/01/2012	0.565	
Complete month	46.275	
Daily average	1.49274194	
Highest	2.857	22/01/2012
Lowest	0.357	01/01/2012

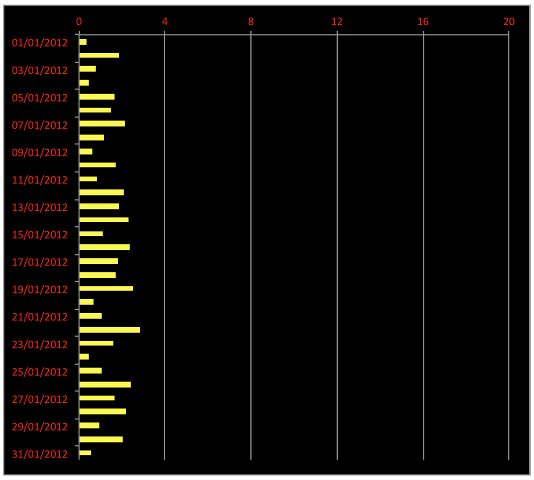

Figure 5-8: Matt's monitoring record showing daily generation figures for January 2012

> *"So I've got quite a lot of these. It is simply because otherwise there is no way of quantifying what impact it makes. So I've got… so you can see how June was very disappointing last year, but in March we generated nearly as much as in June. It was just a really poor summer… I think we might have lost 100 units in last June, so*

> *you get a bad summer month and it has a lot more impact than a bad winter month… its interesting seeing the patterns, so that is in the winter, it is hardly generating anything (laughs)… But you talk to some people who say 'yes, I think it's made a difference and I think it was good', but they've got no way of quantifying it. And it would have been hard for us to quantify what impact it had had if I hadn't done this*." (Matt, householder, September 2013)

Matt's interest in quantification here, as with the other users in this research is not purely an interest in money. Although it is important for him to know that his panels are generating enough to match the predictions on his Return On Investment calculations, this is not his only interest. Rather he is curious about knowing *what it is actually doing* as a situated technology and how this relates to his local weather. During this ethnography, people would frequently use phrases such as 'a bad summer' or 'a good January' in a similar ways to those associated with practices of gardening or farming, as a way of living with indeterminacy and distributed agency. Knowing what weather and generation had been like did not enable future prediction or stability, but rather were a way of learning to be with them. Drawing comparisons to the experiential knowledge involved in farming practices like vine work, where "Previous experience and acquired knowledge provided possibilities, but not certainties" (Krzywoszynska 2015), enables a less instrumental understanding of Matt's enactments in quantification. Knowing what solar panels did last month or year will not provide him with control in any managerial sense. It is not knowledge he can put to use in order to make the most of his electricity generation. It is a way of learning to be with solar, with all the indeterminacy and surprise of action this brings.

Coming to know and be with solar electricity in the first year was then not just a matter of knowing solar better, developing understandings of the technology and the temporal patterns of generation, but also of being affected by solar. In particular about coming to notice local weather and putting this in relation to energy generation and consumption. When I speak to Rory after the first year, he tells me how he notices weather in a different way. Not just sunlight in relation to solar electricity, but in relation to all that grows, particularly as he has been spending a lot more time in the garden, since being made redundant. A different kind of attentiveness to weather and temporality has begun forming:

> *"I'm really into slow stuff at the moment, slow travel like cycling. Taking time to get where you want to be, rather than having it now. So growing your own food and taking time for it and the same with the energy; having it when it is available and not always taking it for granted. So sometimes when it rains I kind of think ahh, we won't be generating much electricity right now, but then I think that the plants in the garden need the rain and you can't have both".* (Rory, householder, August 2013)

Being affected by solar as Rory explains it here was an achievement of a very particular assemblage which had a lot to do with a number of other things specific to his life 'coming together' which meant that solar panels for Rory had a lot to do with gardening, cycling and generally 'having more time'. In contrast to Rory, Peter doesn't do gardening. And he is not at home during the day as much as Rory is. He does not have anything near the amount of devices and sources of information that for example Simon mentioned at the beginning of this chapter who lives on the same street has, and he spends a fraction of the amount of time Simon spends on monitoring. But every day, at the same time, just about when the sun goes down, Peter goes and reads the generation meter. He notes down the number with a pen, and transfers this number to the calendar on the wall in the kitchen, where the PV system has been allocated a row on the right hand side, as illustrated in figure 5-9 below. The calendar also holds information of various appointments, birthdays or other kinds of events that are important to him and his wife Anne. The generation figures become part of the temporality of daily life. Peter will consider the differences between the days, notice good and bad days, consider how these relate to the weather, to the season or as time went on to previous months and years. As is the case for all the other ways of monitoring generation, these efforts of keeping track do not result in a form of knowledge that he is able to use to make the technology more predictable or useful for him. Instead it is an enactment of living with the indeterminacy of the weather and its impact on his energy generation and his investment in solar. It is a way of knowing *'that they are doing something'* and it is something that he occasionally shares with people he knows or meets who are interested in solar panels, like family members, colleagues or researchers.

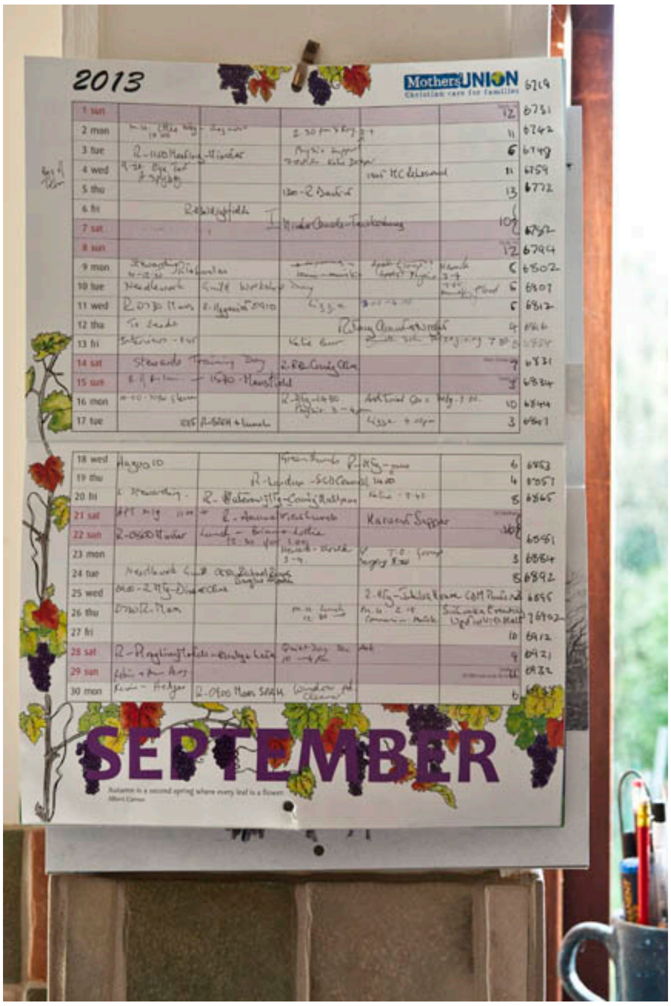

Figure 5-9: Peter and Anne's calendar showing daily generation figures in the right hand margin

Anne, who has the main responsibility for the running of appliances in the household, is not terribly interested in these numbers. This is not a general disinterest in all numbers or quantities as such, but these are not useful numbers for her. Trying to draw direct links between instantaneous generation and generation in the immediate future is a different enactment than monitoring: *"I look out of the window instead,"* she says. Knowing what the panels did yesterday is not of much use if you are trying to decide whether to put on a load of washing here and now, looking out of the window provides better real time "data" and even some indication of what might happen in the immediate future, if you know how to read clouds, something which it is very difficult for the monitoring devices to do.

What these efforts of keeping track show, is something about the indeterminacy and connectedness of domestic PV and the uncertainties of living with an intermittent power. Whereas people do not question the availability of electricity coming into their houses from the grid, solar electricity is different. Coming to know it and coming to know how best to use it involves developing experiential and situated knowledges and numerical representation provides an important means of doing this.

5.3.1 Qualculation

The division of labour between Peter and Anne into enactments of either keeping track of solar or making use of it was rarely that neat, neither in their household nor in other households involved in this research. People did not either enact solar monitoring or solar usage, but rather a mixture of both. The relationship between PV information and PV action however is very far from linear. Efforts of translating or making electricity flows visible as numbers, are particularly dominant on the Microgen Forum, where PV is enacted primarily through comparison. As this is the manner in which PV is made to matter on the forum people will initiate threads and post comments, where they have "done the maths" in advance. What becomes clear through reading these posts however is that doing the maths does not always result in clarity or a clear path of action. Increased understanding of the quantity of electricity available at specific times creates not just certainty, but also opens up uncertainty elsewhere. Questions asked by users in different threads on the Microgen Forum illustrate this:

> *"is it worth washing the panels to increase generation capacity?"... "does shading have such big an impact that it will be worth felling the tree in the back garden?"... and "is it a good idea to buy a low-wattage kettle*?" (Microgen forum users, January 2014).

Attempting to find answers for questions like these becomes part of engaging with this information: as relative certainty is achieved in one place, uncertainty proliferates elsewhere. Doing the right thing is not just a matter of responding to one particular cause-effect or source of information, but rather choosing which kind of information, when and where it is relevant to respond to, whilst ignoring other kinds of information. As Callon and Law have asserted: the distinction between rational or irrational behaviour is very much a matter of frameworks (Callon and Law 2005). Whilst a lot of numerical information is produced, manipulated and shared on this forum, the question of how best to respond to solar electricity also involves non-numerical and local components: issues like concern about the environment or questions about quality of life. Issues which are not quantifiable in the same manner as kWhs and which add disparate and difficult components to the kinds of everyday algorithms people employ to answer questions like: *"is it really worth it using that slow cooker*?" (Microgen forum user, January 2014))

The notion of qualculation provides a useful way of understanding these processes of trying to turn the multiple experiential and numerical knowledges of solar into guidelines for action. Franck Cochoy has employed the notion of qualculation in his study on 'shopping cart arithmetic': a quality-based rational form of decision making which includes both numerical calculation and judgment (Cochoy 2008, see also Callon and Law 2005). What Cochoy found, having carried out long term participant observation combined with a one year multi-methods study, was that the properties of the shopping cart contributed to and modified consumers calculations(Cochoy 2008). Not only did the shopping cart add complexity by combining a budgetary constraint with a volumetric one, it emerged as a 'scene' where it became possible for Cochoy to observe how a number of elements like shopping lists, information on packaging, concerns about price on the one hand and needs of the family on the other were adjusted and negotiated:

> "The combination of these elements moves the consumer from mere calculation (price-based computing) to 'qualculation' (i.e. quality-based rational judgements)… a shopping cart functions as a scene or as a frame for collective 'calqulation' (from the French verb 'calquer', i.e. adjusting one's stand- point to that of another, and vice versa)" (Cochoy 2008: 15).

This notion of qualculation I think is particularly useful for understanding enactments of domestic solar, because it enables a focus on how learning to know and use it is not a straightforward reaction to certain information about flows of electricity, but consists of both the manipulation of numbers, evaluations of best choice in the absence of 'clean' numerical information, and value-based choices about the impact on everyday life of changes to habits, and wider environmental effects. In this scene what is *the right thing to do* is the outcome of many different local and temporal considerations. Qualculation, unlike calculation cannot be achieved once and for all, rather it focuses attention instead on the material arrangement that enables particular components to become weighted and considered, understood as "the manipulation of objects within a single spatiotemporal frame – which can be done in indefinitely many ways" (Callon and Law 2005: 719).

With this view of the manipulation of numbers, the issue in focus is not merely the question of whether or not the use of them as representatives of quantitative externalities results in useful guidelines. Rather it focuses attention on the question of how locally enacted qualculations enables the selection of some calculative components over others. It also begins to explain why qualculation was on-going, when I came back to visit households a year later or when I analysed comments on the Microgen Forum from users who had lived with solar for a number of years. Neither the annual output from the solar panels, their particular patterns of power over the seasons, the configuration of devices inside the household nor the valuations of household finances or concern for the environment were stable components.

> *" I suppose I kind of don't think about it all the time anymore, but you can't just always put your washing machine on at the same time, like you know we did that with Economy 7. Because there isn't always sunlight at the same time of day, so you have to kind of notice what the weather is doing. So often I'll notice that it is sunny and then I'll go and see if we have washing to do"* (Claire, householder, September 2013).

Energy users will often tune their energy use when a new device is introduced. The research on smart meters for example has shown how people do become more knowledgeable about their consumption and make changes. It has also suggested however that smart meters might make but not keep energy visible: that they get backgrounded or forgotten about after a while, once people have become equipped with the information they have to offer (Hargreaves, Nye et al. 2013). Living with a PV monitor is not the same as living with a smart meter, just like living with solar electricity is different to living with Economy 7. As the quote above shows Claire is not responding to information about energy, she is using a particular kind of energy. One which does not enable you to just switch one temporal routine with another, but rather requires you to respond to the weather. You cannot come to know that kind of energy once and for all: it is not a passive resource. In the following section I consider how different devices are involved in intra-action with this active, temporal and vibrant power.

5.4 Powering appliances: using up electricity

The recommendation of 'making the most' of the daily electricity generation, made good sense to the majority of PV users in this research. This recommendation did not just come from installers or different kind of media coverage of the potential of solar, but from other notions of thrift and economy in relation to other resources (Evans 2011). In some cases it also came from the environment itself: *"In a way it's a bit like a gift from the cosmos"* said Mark and explained how this came with a certain imperative to *"get it right, make the most of it".* Making the most of it, was enacted almost exclusively as load shifting: making changes to the times of day electricity is used, has been and continually is a challenge in daily life in the PV households I came to know. As the illustrations of patterns of power at the beginning of this chapter showed however, the patterns of solar generation provide a particular challenge for many households, which the temporality of daily life is not easy to shift to. Many daily events such as cooking, watching TV and having lights on, were not events that solar panels had much impact on, because they were events which were situated temporally according to other frameworks which were not that easily shifted (Shove 2003) or where the specific timing of them were what made them useful and meaningful. In a single household a slow cooker was purchased in an effort to shift some of the load of cooking from evening to daytime, but other than this, these were events that solar panels had very little bearing on. Likewise the 'background stuff', like fridges and freezers got very little mention, except to say that they were not possible to shift. Two categories of electrical devices were left: devices that can be charged up, and devices involved in washing; dishwashers, washing machines and tumble driers. These were the devices that people felt could operate at any time of the day in response to solar generation, without disrupting the flow of everyday life.

The charging up of devices was most often mentioned as events that could fairly easily be temporally shifted, however not without some degree of insecurity as to the actual gain involved, particularly as flows of electricity were difficult to control even with charging devices:

> *"I now always try to put my toothbrush on to charge during the day, where before I would charge it overnight. But it's still difficult getting it completely right, because then I often forget to unplug it when I come home" (John, householder, September 2013).*

> *"If I'm not taking the laptop with me to work, I try to charge it whilst I'm out. But of course you can't tell it to wait until peak generation, it just goes ahead, and I leave at 7.30am so I'm not really sure how much of it is actually solar" (Sarah, householder, July 2013).*

Different patterns of charging small appliances like electric toothbrushes or mobile phones were often mentioned as form of energy consumption that people had changed.

It is worth briefly considering the numbers involved here. An electrical toothbrush typically uses about 5 watts to charge, which assuming it is charging for 10 hours amounts to a total consumption on that day of 0,05 kWh. In relation to the average annual household electricity consumption of 3,300 kWh (Owen 2012), this is a very small change. Related to this was an even smaller change, which was frequently mentioned: making sure that chargers were all switched off and unplugged during the night. Although it does not make a significant difference to actual energy consumption it is nevertheless an important change to consider, because it begins to illustrate the messiness and difficulty of establishing exactly what the consequences of different changes or different enactments of 'doing your bit' for the environment are. Charging devices is an area of consumption, which solar can have effect on, something which recent efforts to improve solar batteries, rely on. It is also however an area of ambiguity. Switching off mobile phone chargers is one of the examples David MacKay uses in his efforts to clarify and quantify different enactments of sustainable energy:

> " I'm not saying that you shouldn't switch phone chargers off. But don't be duped by the mantra "every little helps." Obsessively switching off the phone-charger is like bailing the Titanic with a teaspoon. Do switch it off, but please be aware how tiny a gesture it is. All the energy saved in switching off your charger for one day is used up in one second of car driving. The energy saved in switching off the charger for one year is equal to the energy in a single hot bath. Your charger is only a tiny fraction of your total energy consumption. If everyone does a little, we'll achieve only a little (MacKay 2008: 3).

Matt who has spent some time investigating the energy consumption of a number of devices using a smart meter has arrived at the same conclusion. He continues to charge his iPhone during daytime, but says

"It really doesn't matter. Some things I think people don't know how much they are using, but other things actually use a lot less than people think. So I know with this it doesn't make a significant difference. If all people change are these sorts of things, then its probably not really making any difference" (Matt, householder, September 2013).

The challenge of load shifting then involved not merely establishing energy uses which could be shifted in time, but also considering in more detail which loads were appropriate to shift. Doing this involved a more detailed knowledge of different devices than the majority of householders were used to doing on an everyday basis, specifically required them to consider notions of *power* and *load* rather than simply *energy*: Whilst some devices use a small amount of power over a long period of time others use a lot of power in a short period of time. As the challenge of using up solar became enacted in these households it became a challenge which was not so much about using less energy, but rather using the appropriate amounts of power at the right points in time. The following subsections consider the specific challenges of engaging with solar power as opposed to energy in everyday enactments.

5.4.1 Amenable appliances

Figure 5-10: Switchable devices - the washing machine

The appliances which were most impacted by the arrival of solar panels in the households, were the washing machine, the dishwasher and the tumble dryer. These are also the appliances identified by the Household Electricity Use Survey as 'switchable' (Palmer, Terry et al. 2013). In all households these appliances were the main point of exchange between solar electricity generation and electricity consumption. Although the challenge of being out at work during hours of peak generation were much talked about in relation to load shifting, washing machines were mentioned frequently as appliances which would operate whilst people were out of the house, as they had timers which could be programmed to start midday. Despite knowing when to estimate peak generation and being able to set the timer, washing clothes using solar power involves the unpredictability of the British weather. This is of course not a problem for the functioning of the washing machine. And for the clothes inside it, there is no material significance either, for the householders this is more a matter of accountability: of knowing if that peak in the load curve which happens when the washing machine starts up, might happen to match a peak in generation.

The Simpsons both work during the day, but being keen to use the free electricity from their panels, have got into the habit of either pushing their washing until the weekend or washing during the day, using the timer on their washing machine. Their monitoring of panel performance and interest in details about exactly how much electricity their washing machine uses is quite low. They don't know for sure when their system is generating the most electricity or how this relates to how much the washing machine uses, but they think that the system has its peak performance around 1pm, so they generally set the timer for then. The extent to which the washing actually gets washed by the solar power or by mains electricity, is not something they consider very much, the most important thing after all is that there is clean washing when they get home:

> *"Sometimes we come home and it has been raining all day and the washing clearly hasn't been done on solar power (laughs), but it has still been done, and other days it does work" (*Bridget, householder, October 2013*).*

Washing clothes relates to much wider practices than trying to use up solar electricity and would have been done anyway in the Simpsons household. Solar electricity did not have the force to challenge this. It had the force to tune or adjust the enactment of it in the majority of households however, or to add temporal flexibility to the practice. As in many households where this happened there was no expectation of any kind of managerial control over solar, people did not rely on solar to do the washing always, or form a new habit of always washing at a particular time. Emerging solar habits formed not according to notions of habits as mechanic or automatic behaviours but rather as a "mode of encountering materiality and life" (Grosz 2013). Clean clothes are a necessity;

clean clothes, which have been cleaned by free and green energy, are *"a bonus*", something that *"feels nice".*

In the households where a lot of monitoring devices are involved, the coordination of weather, technology and time becomes more complex. Using his Watson smart meter, Matt has investigated the energy consumption of a number of appliances in the house, that he uses the most:

> *"The washing machine uses about 2 - 2.5 kW, depending on program, to heat up the water, which takes about 15 minutes early in the program, and then it uses around 1 - 1.5 kW when it's spinning"* (Matt, householder, September 2013)

The more detailed information however, does not make it easier for Matt to make sure he washes his clothes using solar electricity,

> "*You really can't plan unless it's a really sunny day. If it's sunny and then cloudy it always seems to coincide the wrong way with the sun*!" (Matt, householder, September 2013)

Getting the timing right and trying to actually use some of the power that their panels generate was something that people I spoke to put a lot of effort into. Timing specific uses of solar power however is a different kind of enactment than "just" using less energy. You are working with multiple forces:

> *"So I look at the weather forecast and see if there is a period around lunchtime or early afternoon where clear skies are forecast. And then I hope the weather does what the forecast said. But at the end of the day this is the weather, you just can't tell. So then I sit there sometimes at work and look out the window at the time we have set it for (laughs), it is pretty silly really"* (John, householder, September 2013*)*

The relationship between timing, weather and washing in the households was significant in two ways. It was involved in new enactments of and sensitivities towards "the weather", but it was also a very clear example of the practical difficulty and complexity doing 'the right thing' according to situated qualculation. Solar panels showed very significantly in these houses that they do have the capacity to disrupt the timing of dishwashing and washing machine usage, at least during summer months. Almost all householders in the case study reported after a year that at least most of the time, they still used the washing machine at lunchtime, if it was a sunny day. This was not a predictable pattern however, as Claire's reference to Economy 7 highlights. Whilst this could then be seen to constitute an example of what Marres refers to as a 'change of no change' (Marres 2012: 66), in the sense that the overall level of household consumption was sustained, it is not of course a situation of no change further 'down the line' of the electricity network, where attempts at using electricity 'as the sun shines' adds complexity to the task of balancing electricity networks as described in section 4.2.4. Washing machines in this research then were powered differently rather than powered less. Other devices had more ambiguous relationships with solar energy, particularly the tumble drier.

5.4.2 Ambiguous assemblages: Drying while the sun shines

Practices of washing clothes and particularly the use of washing machines as part of those were not just 'switchable' in relation to solar panels as the example of load shifting with Economy 7 illustrated. Putting the washing machine on during the day, when the sun shines, made perfect sense not just financially but also practically particularly when people were at home during the day and had the opportunity of hanging the washing out on the line. Like washing machines, tumble dryers turned out to be very important albeit ambiguous devices, in relation to solar electricity.

Tumble dryers are known for being bad “energy users”. In the UK they use on average 394 kWh of electricity a year, drying an average of 260 loads annually (Owen 2012). Despite being known for their heavy electricity consumption, tumble dryers were crucial devices in the majority of the UK households I visited; devices that enabled children to go to school in clean uniforms, or allowed towels to be dried in the winter without causing damp in the house from hanging for days on a clothes horse. As the challenge of using up daytime solar electricity was introduced, they very importantly also became devices that were able to use up ‘spare electricity’ in some households.

Tumble dryers are often seasonal devices. Considering their energy consumption in the light of having solar panels, people in this ethnography would mention the troubled relationship between tumble dryer and solar panels: That tumble dryers are mainly needed to dry clothes in the winter, where solar panels are not capable of producing much electricity. This was something people had mostly already considered at the time of investing in solar panels, but it was also something that a number of them used as an example of why new habits they had acquired during the summer, weren’t maintained in the winter. This was not a matter of complacency or indifference, but calculation. It doesn’t make a big difference when you use electricity in the winter, because the smaller amount of energy generated does not make much of a difference to energy bills:

> *“If there is a really clear sunny day, then the panels do really well. In fact I have been surprised at how well it can work in the winter. But there is only about 3 of those days in one winter, most days we make something like 20 pence (laughs)… there’s just no point changing anything for that”* (Patricia, householder, July 2013)

The seasonal relationship between tumble dryers and solar panels is not at all stable. In some households, tumble dryers have succeeded in making themselves useful in the summer, not despite their high electricity consumption, but because of it: Mark and Sally know about the relationship between their energy generation and their energy consumption via their electricity meter, which winds backwards when their panels generate electricity. This means that they put a lot of effort into using up the electricity their panels "wind back" during the day. During the weekend they do this real time, and the tumble dryer has become crucial in this effort: Mark explains:

> *"it did definitely change the way we use stuff. I guess when we can see the meter spinning backwards like this, we did sort of on those times start using the tumble dryer in the middle of summer and stuff like that, which we wouldn't normally have done, because it's free and not hurting the climate sort of thing. So we'd move stuff into the middle of the day, like the dishwasher and the tumble dryer and what else we've got would tend to go on in the middle of the day if we're around"* (Mark, householder, October 2013)

In this assemblage, the tumble dryer's ability to use up around 1,5 kWh of electricity on drying one load of washing is an affordance; it enables for the using up of a substantial amount of free electricity, which would have otherwise been "lost". Mark and Sally have a big 4 kWp system, which means that efforts like charging small appliances or engaging in other kinds of low level electricity usage, makes hardly any difference to their meter winding backwards. But with the tumble dryer, they are better positioned to use up their free electricity, and actually see, just by looking at the meter, that the electricity is indeed being used. It's a new way of thinking about electricity and a new way of drying clothes, which Sally explains has taken her some time to adapt to:

> “*We use the tumble dryer more in the summer, although I’m still in the habit of putting it out on the line, which is silly really given that it could be completely free in the tumble drier. I suppose that is just a bit of a crazy head, growing up in the 70s; everything went on the line* (she laughs)” (Sally, householder, October 2013).

It is important to notice that the solar energy enacted here is *double free*; it is not just free in terms of not costing any money, but also free in the sense that it is not, as Mark puts it *hurting the environment* in the manner that fossil fuels do. Not all informants in this ethnography increased their use of tumble dryers. What is interesting about this increased use is not the potential extent of it, but rather the logic behind it. Mark’s understanding of solar electricity was not uncommon amongst the householders or the users of the Microgen-forum: If electricity is enacted in a manner where it does not cost anything to use and it does not have adverse effect on the environment to use it, using as much of it as possible makes very good sense. ‘Saving by consuming’ however was a difficult enactment to get right, as already seen, not least because solar electricity is difficult to know and predict. The enactments of using and monitoring PV electricity described so far have highlighted the many ways in which accountability for energy flows is difficult to achieve. This is not a difficulty that is an issue and a challenge purely for householders, but also in relation to the wider energy system and potential carbon savings. Solar electricity does not simply flow into the household, but also out of it. The domestic household is not the end. This makes solar electricity a different kind of electricity with different performative powers. The manner in which solar electricity co-exists with grid electricity highlights the complexity of ‘making the most’ and ‘getting it right’.

5.5 Domestic flows -living with electricity on the move

I have illustrated so far how negotiations of information and power went on in solar powered households and that solar electricity was not a passive resource, but rather a vibrant force (Bennett 2004). It is vibrant not least because of its connections outside the household: those connections which have something to do with how much and when solar electricity is generated as well as those which are involved with backing its powers up and enabling it to flow away from the household. This section considers domestic solar on the move.

5.5.1 Winding back consumption

Whilst the monitoring of generation most often has limited direct instantaneous relation to consumption, in some households a technical issue with electricity meters allows the two to become connected differently. Although this is considered a technical anomaly, it is worth exploring further, because it sheds light on the challenge of living with a kind of electricity, which flows not only into the house, but also out of it. Establishing exact knowledge of flows of electricity in and out of households is difficult, not only for householders but also in relation to the energy system. When conventional electricity flows into the household to be "consumed", householders do not often ask questions of where and how electrons move. Solar electricity changed that for the households I visited. They began wondering about where the electricity their panels generated went, how far it travelled and what use it was put to elsewhere.

In some of the households I visited, the presence of analogue electricity meters foregrounded this issue. Analogue electricity meters were made at a time when electricity moved one way; from the grid, to the household. When it starts to move the other way, from a solar system to the grid, in many cases, so does the meter. This technical problem is dealt with inconsistently. The installer is not responsible for dealing with this issue. It is flagged up in the form that is sent to the utility company, in order to register for the FIT, where the householder is asked to inform the utility company if this is occurring. What happens next varies greatly. Some utilities will come straight out and replace the meter for an electronic one which doesn't present the same problem. Others do nothing. Anecdotal information says that some householders have got into disputes with utility companies about this, but it remains a grey area. In the houses I visited, analogue meters had been an issue in about half of the installations. In some cases the utilities arranged for meters to be changed relatively quickly, but for 3 of the households, the meters were still going backwards 2 years after installation.

When I visited Simon for the first time in November 2011, his analogue meter had been replaced by a digital one, but still presented a problem for him*:*

> *"I had a spread sheet for years, where I religiously read my gas meter and electricity meter and calculated all the sums to check that they were charging me the right amount, and well it really buggered up my spread sheet! I got negative numbers! On the 5th of July we went on holiday for 2weeks, so for 2 weeks in July the meter was going backwards to the tune of 101 units. And that really messed up my spreadsheet! And I still haven't fixed it. It's ridiculous, I've got these big negative numbers where the meter ran backwards, and it's completely thrown me, I cannot for the life of me comprehend how I'm going to calculate… I don't know how much power we were taking from the grid; I just can't measure it, because there is no export meter. That's the big difference between this system and the one in Australia. That guy there has got an export meter, it does measure exactly how much you are exporting as well as what you're generating. So it makes it ever so easy to work out what you're using. But here, well I've got no idea how much we're*

exporting. I know I get paid on half of it, but I just don't know" (Simon, householder, November 2011)

Simon's meter was eventually changed for an electronic one, after he himself contacted the utility company several times. A meter going backwards is essentially stealing from the grid, which as far as Steve is concerned not only messes up your spreadsheets, or makes accountability for the flows of electricity impossible, but is morally wrong, so he went through some effort to have that changed. Adding an export meter to the installation would have been possible although costly to install and from a thread on the Microgen Forum he knew that the majority of the utilities would continue to pay people the deemed 50% export tariff regardless. So for him as well as the majority of users on the Microgen Forum the extent of export was arrived at through calculation rather than metering, as I shall return to in the following section.

Mark and Sally reacted differently to their electricity meter running backwards. When I first visited them in 2011, they had already had the panels for 5 months. As we were talking about their daily engagement with the technology, the issue of the meter came up. At the time they had not put much thought into this and not really considered the impact of this on their engagement with electricity, indeed it was not until I asked them about it that they realised that this was a fault. Instead the meter going backwards and forwards had become their main source of engagement with solar electricity, and created a clear link between the electricity consumed – the kind that makes the meter go forwards, and the electricity produced – the kind that makes the meter go backwards. The following conversation illustrates this (Sally and Mark, householders, December 2011):

Sally*: Mark was obsessed in the beginning. He went out one evening, came back and said to me 'have you had the tumble drier on this evening?' Because it was this number when I went out and it's this number now!'* (they both laugh)

Mark*: It's because our meter runs backwards, and so I knew that if we were reaching sort of 6,7 or 8 on the meter, the next day we could wind it back all the way down to 0 and then start again basically. So having the tumble dryer on pushed it that much closer. So I was obsessing. I'm over that now* (he laughs).

Britta: *does your supplier know that your meter runs backwards?*

Mark: *Yes, well there is a part of the form, which you have to tick if the meter is running backwards and I was kind of expecting them to put a smart meter or something, but they haven't. But I suppose the cost of smart meters is relatively high?*

Britta: *they sometimes come out the next week, but others don't. I suppose they might be weighing up the cost of sending somebody out with how much they are losing?*

Sally: *Is that because there are still so few people who have got solar panels?*

Mark: *Well they may not have worked it out because looking at it, well I guess it's up to 10 units per day isn't it, that you're saving on top of the generation tariff, so if you finish the night with the meter on 9 and I suppose you start the morning with the meter on 9, you've got the opportunity to wind all that back…So it winds it back, then you can use some electricity and then potentially, if it's a very sunny day, you can wind it back again, so you will potentially get through another day without using any mains electricity. Or at least appearing not to. So it's just a nice side effect to it. But, well, they should really have built it into the assumptions,* *because I suppose in one sense we are getting more benefit from it than the figures we got from the illustration, when they gave us a percentage. So I reckon that in the height of the summer we went from using an average of 20 units a day to using about 5, and overall it's a lot lower than that, it's probably about 10 or something like that.*

When I return to talk to Sally and Mark a year and a half later, the meter is still running backwards. In the meantime however, they have invested in a power router which diverts spare solar power to a newly installed immersion heater (a technology which began gaining popularity during the latter part of the ethnography and which I return to in the following section), so it is then used to heat the water first, which means the amount of units that the meter winds back is slightly less. Mark comments: *"but we're still stealing from the grid I suppose"* (Mark, householder, October 2013).

The meter running backwards creates a material link, which connects electricity generated – the kind that goes backwards, with electricity used – the kind that goes forwards. It is not a good representation of electricity usage however. When I visit John and Bridget at the end of October 2013, they explain that they are still 'further back' than they were in February. As the summer of 2013 has been so good, they have not used enough electricity between February and October for it to actually register any consumption:

"But it's difficult to calculate, because our electricity usage has gone up a lot. The kids have got older; they use more electric stuff that needs charging now. We have an iPad and an Xbox they didn't have when you were last here… and everything is being charged daily if not more. But it's difficult because we cannot actually measure what we are using. But it basically means that our electricity consumption, annually, is ridiculous. I can't remember what it is but it is less than a

couple of hundred pounds, and this is quite a big house" (John, householder, September 2013)

Having the meter go backwards this much is problematic in relation to providing meter readings to their electricity provider. John explains that he has to make a number up in order to provide a credible reading.

> *"The hardest thing is providing a reading when I get our monthly bill, because I don't tell them what it is!* (laughs*)…What I do is I just sort of try to average it out, so at the moment we have, according to the electricity company, used more electricity than we have and it will be a little while before we start to catch up. So I'm hoping they won't catch on to this. If they send someone out to read the meter then we are in trouble (*laughs*). We should tell the kids: never open the door to a meter reader! (*laughs*)"* (John, householder, September 2013)

The agency of these meters is as we have seen ambiguous. They are what makes the people who have them some of the most keen advocates for solar technology of all the PV users I came to know, not least by blurring the actual performance of solar; or enacting solar electricity in a manner that makes it seem like the panels are generating a lot more than they actually are. It is unfortunately also what makes it difficult for people to know flows of electricity in both directions, 'hiding' how much grid electricity has been used and therefore making it impossible for people to establish the actual impact solar electricity generation has had on their overall energy consumption. Although the problem with analogue meters is a technical anomaly, they account nicely for the very vibrant materiality of electricity. Knowing exactly how much electricity 'leaves' the individual household at a given point in time and what it is capable of powering and affecting elsewhere, is very difficult. This difficulty and uncertainty is performative, as the following section will show.

5.5.2 When electricity can leave home: the immersion heater debate

The question of how to best use up electricity and prevent export, is not merely a question that occupied the householders I came to know, but also the most debated issue on the Microgen Forum. It is the result of a heterogeneous mix of distributed agencies (Bennett 2005) which makes electricity used in the household appear more valuable (financially and environmentally) than electricity which is not used: the manner in which solar electricity is present, and is ordered both financially, politically and materially translates it into a kind of energy which wants to be used up: which leaves the house if it is not. The initial design of the FIT with a very low export rate and the fact that the level of export was deemed at 50% rather than metered led to a lot of speculation amongst the households I came to know, as to the quantities and impacts of 'their power' as it was exported: *"I'm guessing that it is not a great enough amount for them to bother metering it"* (Veronica, householder, December 2011) and similar assumptions were becoming frequent as part of the talks people told me they had with other PV users.

People did know that technically the unused electricity could be used elsewhere in the energy system, for example by their neighbours, but the uncertainty about how far it could travel and what kind of power it had elsewhere (not least in contrast with the level of numerical detail they could come to know it inside their houses) became performative: It made people doubt if it was actually doing anything useful once it "left the household". And like this, in the absence of tangible evidence of its onward movements, in many of the households I visited, exported electricity became understood by my informants as surplus or even wasted electricity:

> *"I've heard that it just disappears out into the grid and gets wasted"* (Bridget, householder, December 2011).

On the Microgen forum this was a cause of much concern but also the reason for creative co-operation: users working together to find a solution, not just to maximize impact financially but also in terms of interest in energy efficiency and carbon emissions. The most popular solution which began being talked about in 2012 as the issue of 'surplus electricity' became increasingly apparent to users, was employing a device which diverts surplus electricity to an immersion heater instead of exporting it to the grid, thus 'storing' the power in the form of hot water. A thread on the Microgen Forum illustrates this:

> *"Despite my best efforts at scheduling white goods devices to coincide with sunny periods I was exporting well over 60% of my 3710Kw annual generation. So in May 2012 I installed a proportional (to generation and house load) controller, which is connected, to my unvented hot water Cylinder immersion heater. This dumps a large proportion of generation that would be exported, into my hot water tank" (Microgen forum user, January 2014)*

The following 3 graphs are produced by a forum user who, in collaboration with a number of electricity meters, monitoring devices, computer software and a free online service for sharing and comparing PV data called PVOutput, has managed to illustrate the work carried out by a proportional controller as it diverts electricity to the immersion heater. (His comments below each graph)

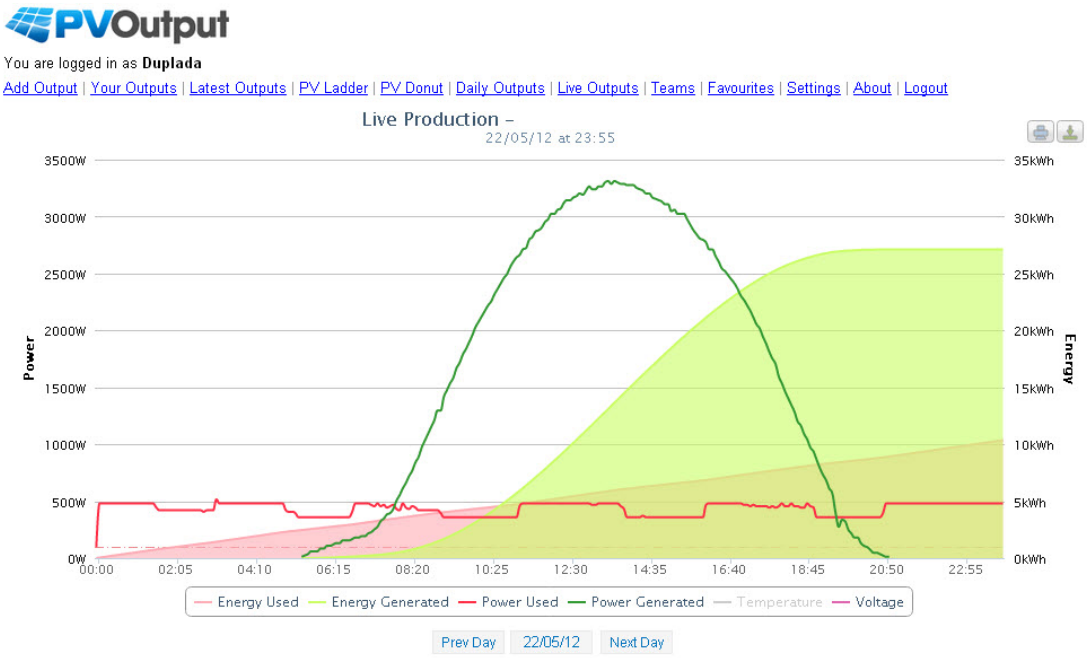

Figure 5-11: PVOutput graph 1 (image from Sheffield Solar Microgen Forum)

> *"Graph 1 shows a more or less perfect generation day whilst I was on holiday in 2012. You can see on the consumption trace the fridge/freezer kicking in periodically" (Microgen forum user, January 2014)*

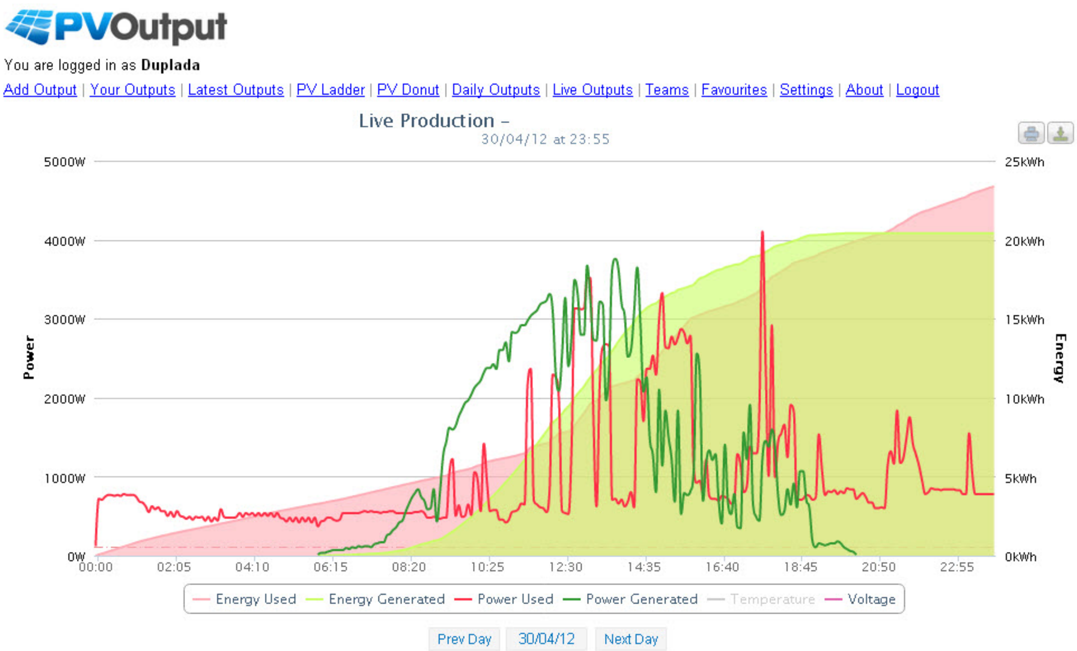

Figure 5-12:PVOutput graph 2 (image from Sheffield Solar Microgen Forum)

"Graph 2 shows a good mornings generation with white goods devices being switched on to take account of the good generation, note the two kettle spikes in the evening and a period where my wife had the electric iron in operation" (Microgen forum user, January 2014)

Figure 5-13: PVOutput graph 3 (image from Sheffield Solar Microgen Forum)

"Graph 3 is for those of you who have been following the information I gave earlier in this thread concerning using a proportional controller to dump PV export into your hot water cylinder. Note how the two traces very closely match each other as the controller adjusts the immersion power to match the PV generation. The sharp ones amongst you will have noticed that with the proportional controller in operation you can no longer graph the real base house load. Well you can but that is a story for another day" (Microgen forum user, January 2014)

Graphs like these or calculations of energy savings to the same effect, often accompanied by ROI calculations provide a fairly convincing case for investing in a power router or proportional controller, if seen over a period of years. The commercial products available at the time came at a cost of several hundred pounds, so was not an investment made lightly. For people who were technically minded and skilled to do a small amount of soldering, schematics for a DIY version, known as "Robin's Mk. 2 Energy Bucket" (Emley 2014) complete with shopping list and instructions, began being talked about on the forum as a few users had built one for a lot less than the commercial product which were now beginning to appear in more models as demand for more clever ways of using up PV electricity was spreading.

Whilst there was general agreement on the forum that immersion heaters and diverter switches provided a good means of preventing export, it became more complicated again, when questions of energy efficiency, sustainability and carbon emissions were asked. Translations between energy, money and carbon are precarious achievements (MacKenzie 2009). Some of the questions asked in forum threads about immersion heater switches and related devices, surface this issue:

> "*Is heating water with electricity instead of gas energy efficient? Is it green?" (Microgen forum user, January 2014)*

> *"Is the immersion heater an energy efficient means of replacing fossil fuels with renewables, or is it simply a dump load?" (Microgen forum user, January 2014)*

Although it is clear the export has indeed been prevented in the example just shown, it is more difficult to work out if this is in fact a good use of energy as the following two comments suggest:

> *"The saving on gas is impressive but do you actually use all that hot water?"* (Microgen forum user, January 2014)

"A proportional controller is only worth the money if you have something you want to use (filling the hot water tank just to "leverage" the system isn't worth it unless it's being used)." (Microgen forum user, January 2014)

The accountability or calculability of solar electricity thus becomes increasingly complicated as kWh of solar electricity become cubic meters of hot water, and the distinction between 'energy in' and 'energy out' becomes more difficult to account for. At the time of my second round of household visits only one household had recently installed this kind of system and had not yet done any calculations of its effects. 2 others were in the process of researching the issue both in terms of Return on Investment calculations and in terms of environmental impact, as were a number of people on the forum. On one thread from the beginning of 2013, some of the comments went like this:

"Firstly, I agree that using electricity to heat water is not very green. Solar thermal would be the way to go here. However the FIT payments and (lack of) renewable heat subsidies make it more worthwhile to go for PV and an immersion controller." (Microgen forum use, January 2014)

"My take on this is that, a lot of being "green" means that you produce locally and use locally. It doesn't really matter that PV is not the most efficient method of heating water it's about using all the available PV generation for purposes that current technology allows. Anything we do with our generation will reduce the load on the energy companies and surely that is a positive." (Microgen forum user, January 2014)

"As usual, you can apportion the stats to suit so it's difficult to determine the underlying truth on CO2 emissions" (Microgen forum user, January 2014)

Holding PV accountable in relation to carbon emissions then turns out to be a lot less simple than the switching of units between '£', 'kWh' and 'CO2' on the PV monitor, not only because of the difficulty of accounting for what solar panels do, but to a great deal because of difficulties of accounting for what happens when electricity enters the grid, which is not only differently carbonised at different times, but also associated with transmission and distribution losses. In terms of getting 'to the truth' of what happens to the exported electricity, domestic PV monitoring devices provide less reliable information:

> "*Since I've had my marvellous GEO Chorus II monitor I have yet to identify a point in time when I'm exporting anything meaningful to the grid during peak usage hours, except for a short period during the summer, weather permitting. This means it is not probably being used immediately. It cannot be stored in the grid, I imagine, and much is lost through infrastructure losses unless used immediately. This IS wasteful, isn't it? It is, surely, far more efficient and "green" to use the generation created locally for your PV system than to lose it through losses in the grid!"* (Microgen forum user, January 2014)

The connection to the grid is ambiguous. What the grid does so well is exactly to make electricity invisible: it becomes something you do not need to understand or worry about. But the grid is also known to be wasteful: transmission and distribution losses from the grid are something people might not know the exact extent or mechanics of, but that they have certainly heard about. So what emerges in this assemblage is a type of electricity, which via monitoring devices is made visible as quantities flowing through the household, but which remains invisible outside it particularly as it *disappears into the grid.*

The issue of waste however was not merely a matter of the loss of potential individual gains, but also a consideration in relation to enabling optimum benefit of PV technology more widely. As their experiential knowledge of the characteristics of their situated powers and of the particular properties of solar electricity more generally grew, many of the users began questioning the effectiveness of domestic installations.

When I first visited Mark and Sally one winter evening in 2011, they had only just both got in from work and managed to feed their children and put them to bed by the time I arrived and Mark was in the process of cooking dinner for Sally and himself.

> *"You know, I work in a primary school,"* Sally explains, whilst Mark is making cups of tea. *"… and a couple of my colleagues also have solar so we talk about it quite a lot. You know, how are your panels doing kind of thing. And then we were talking today, because it was a nice sunny day, about all this electricity, which we weren't using in our houses. But at the same time at school we use a lot, we have computers on all the time, lights, TVs all sorts of things, and we were thinking that it is actually really stupid that we have panels on our houses, and not in school where we actually use electricity during the day. So we've just got home now and at this time of year there is no more sunlight. So it's a bit of a waste. And it is of course because of the Feed-in Tariff that people put them on their houses, but really it ought to be a no brainer that they should go on schools and offices and hospitals and places like that which use electricity during the day*".
>
> Mark joins the conversation: *"it makes you wonder, because obviously it is more effective to use electricity where it is generated, but surely it must have occurred to them that the people who could afford to invest in panels, would not be people who were at home during the day, so the electricity is not actually being used where it is being generated, which means there must be a lot of waste"* (Mark and Sally, householders, December 2011)

The notion of waste became increasingly employed in the latter part of the ethnography, which I return to in section 5.6.3. Before that it is important to introduce a complementary notion, which emerged simultaneously: the notion of optimum performance.

5.6 The complex balance between optimum performance and waste

Efforts of coming to know solar were complex as already discussed. The availability of monitors, modelling software and websites for comparison of data give the illusion of an object which can be known with calculative and scientific accuracy through the use of calculative and scientific methods. At a closer look however, this was a problematic enactment as the vibrancy and indeterminacy of powers and weather and other materialities and forces had to be assembled and aligned outside the laboratory. This section is concerned with solar as it becomes an object of "research in the wild" (Callon and Rabeharisoa 2003).

5.6.1 To clean or not to clean

The framing of PV as a domestic or personal portion of energy, which can be kept track of by numbers at least within the household, it something which it has been suggested might help people consider energy differently, now that they are both consumers and producers. The notion of the 'prosumer' is often used in relation to domestic PV users. This was not a term, which the PV users I came to know identified much with however. Sarah's response to the question provides a good example of how people reacted when I introduced the notion to them:

> *"It's a bit like growing a few vegetables in your back garden isn't it, that hardly makes you a farmer!"* (Sarah, householder, September 2013)

The new notion of domestic energy production did introduce something new in many homes however. With PV already being framed through enactments of qualculation, the performativity of numbers (Callon 1998, Barnes and Hannah 2001) spread also to the question of production. What was most noticeable however was not the romantic notion of ownership connoting from some uses of the term prosumer, rather it was more in line with a kind of concern about running a financially and environmentally viable operation. As people were interested in how to secure optimum benefit from their solar panels through the way they used the electricity, both in terms of financial Return on Investment and in terms of reduction of carbon emissions, many users became interested in making sure that panels generated as much as possible. This would open up question of shading for example which resulted in two large trees being cut down during the duration of my ethnography, concerns about pigeon droppings on panels impacting generation and increasingly (as installations had been up for more than a year) the question of whether or not to clean the panels.

The notion that people could impact and improve generation was an issue, which emerged as PV users both in households I visited and on the forum gained increasing experiential knowledge and experience of being with solar panels. In 2013 and the beginning of 2014, the question of panel cleaning was one of the most debated on the Microgen forum. Solar panels gather dust and dirt. Sometimes they also gather bird droppings. For panels installed near particular industries, farms or motorways this might have a significant negative impact on their performance. They might need cleaning to continue to generate their optimum output. Other panels are installed in areas where there is less dust build-up, where the rain does an adequate job of cleaning them. The angle they are fitted at might impact on this. Deciding how dirty a solar panel is however can be more complicated than it seems, particularly as the performativity of monitoring comes to frame it as a question of numbers. Within an assemblage where the output from solar panels is enacted as numbers, an expectation of general, even scientifically certain answers is not altogether surprising. In a thread about panel cleaning, the Solar Farm is called upon for advice:

> *"It would be useful for the forum to know what Sheffield University does! Clean or not clean? THAT is the question! Perhaps you could tell us.... Sheffield, you are in the driving seat here. As a research establishment what are you finding with regards to cleaning? Don't sit on the array! Give us the benefit of your research*."
> (Microgen forum user, January 2014)

As can be seen by the quote above asking for academic research about this, dirt on local solar panels becomes a very different presence to dirt for example on windows. Trying to establish the impact of a dirty panel on overall system performance is one thing, but then adding the cost of a potential cleaning to a ROI calculation, particularly if panels are out of reach and need to be cleaned by a professional company, is quite another. A forum user shares his concerns about this:

> *"Normally I've found the rain does all the cleaning that's necessary on our setup. It's just that lately we haven't had any and I noticed the maximum solar output was a bit down on what I was expecting. This, combined with the fact that the car roof and rear window (which hadn't been cleaned either) also had a thick covering of brown dust, led me to see if cleaning increased the output of the panels*" (Microgen forum user, January 2014)

For people whose panels are not so obviously dirty that it can be spotted simply by looking at the panels, performance data analysis is called upon to help establish whether or not a cleaning is required. Establishing from the data whether a drop in output is due to dust, weather or a technical problem, is very difficult however. It's a dilemma of the local and the general: it is difficult to establish just how dirty a panel is without having something to compare with, but on the other hand it is difficult to say anything in general about this issue, as all domestic installations are affected by local conditions. As the quote at the beginning of this section implies, there are nevertheless a number of calls on Sheffield Solar, to provide some kind of scientific answer:

> *"We need someone with multiple arrays that are separately instrumented to do some tests for us by cleaning one array and leaving another dirty - then comparing the outputs during and after cleaning. Someone with a Solar Farm perhaps!"* (Microgen forum user, January 2014)

Sheffield Solar however, despite being housed in a physics department and staffed by scientists, cannot provide a general, scientific answer to this question. For them this is a local question, it depends on the particular amount of dirt in question. Dr. Lisa Clark at Sheffield Solar sees it this way:

> *" So it's really difficult because it is as if someone was to write into the farm and say 'should I clean my windows today?' 'Well, do your windows look dirty?' And that's a really hard thing to quantify and a really hard thing to write back to them. Somebody in the industry could probably look at them and say 'you really need to clean them', but for us its more like 'if you are having to ask me that, you probably don't need them cleaned'"* (Lisa Clark, solar researcher, January 2014)

The difficulty is establishing how big a problem the dirt on the panels is, and unless it is an obvious case, this is almost impossible to determine, whether you have a solar test bed or just a domestic installation. Lisa Clark explains:

> *"With scientific rigour you can look at a particular panel, you can test how much difference in generation there is, and how much you have spent on gaining how*

much. The problem is quantifying that initially. Because you can't clean one panel and see, because they are all in series. You could potentially clean off the bottom of a strip but then it just becomes a bit silly. So then it really is a judgment of your panels. If you can still see the panel structure on the arrays then as a whole you don't need to clean them. But if you start seeing muck on them so that you can't make out the panel, then you need to clean it. If you ask a panel cleaner they'll always say it needs cleaning." (Lisa Clark, solar researcher, January 2014)

Judgments like these are difficult to make, when you have nothing to compare with. It is again an enactment of qualculation and of the indeterminacy and complexity of how solar panels work as situated powers. Accounting for cause-effect relationships when it comes to performance is difficult, as the following model and consideration from a forum user who has cleaned his panels illustrates:

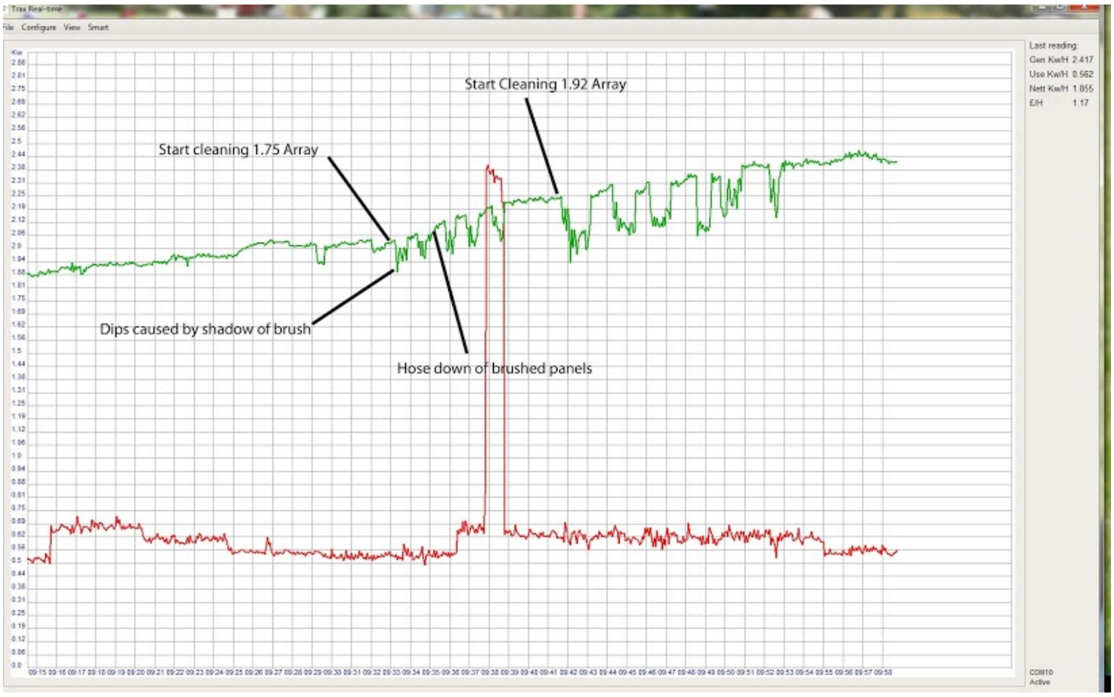

Figure 5-14: Generation graphs representing instantaneous impact from panel cleaning (image from Sheffield Solar Microgen Forum)

"The solar output during both the cleaning sessions as monitored with an Eco eye Smart PV (which updates every 4 seconds) is posted here [above] *together with a photo of our installation. Quantitative assessment is difficult due to the variability of the solar output, but if you extrapolate the output before the cleaning using a straight edge it could be argued that it did some good. If you're wondering how I managed to brush the panels, I used a soft brush taped to one of these* [hyperlink]" (Microgen forum user, February 2014*)*

The comment about the impact of dips caused by the shadow of the brush shows something of the difficulty of getting a clear answer to the cleaning question; because of the difficulty of knowing exactly what the numbers achieved is a representation of. A few days later, the person who posted this, had spent some time contemplating this difficulty of establishing exactly what has been captured in his green line:

"Further to my earlier post where I produced some graphs to show how the output of our panels increased slightly during cleaning. It has occurred to me that some (or all) of the increase in output was due to the panels being cooled by the water that I squirted over them!" (Microgen forum user, February 2014*)*

The users on this forum are mostly very capable of using and making sense of various kinds of accounting and data manipulation tools, but this is a frequent problem: establishing exactly what it is that has been captured in the numbers in a situation where you have no means of isolating sources of agency. And the more information is assembled: in this case that both shading and temperature affects performance, the more possible reasons for the numerical outcome can be found and possible explanations proliferate (Callon and Law 2005). The threads on the forum dealing with this issue therefore do not arrive at a general conclusion. There is not anymore certainty at the end of the threads than at the beginning. Often it is a case of some people having performed experiments, which indicate an increase in performance whilst others have found the opposite. Carrying out experiments like the one above 'in the wild' does not enable the amount of control you have in a scientific laboratory (Latour and Woolgar 1979).

As indicated in Lisa Clark's comment earlier however, there are commercial companies who are capable of determining issues like this without the levels of doubt seen so far. Forum users are aware of this too, as this warning from one suggests:

> *"Having just completed a short trawl for solar panel cleaning companies, it seems that there are now a proliferation of them! Domestic as well as commercial. Whilst I'm an advocate of cleaning panels occasionally and appreciate that, for those who don't appreciate heights, this may be an option; it seems the next generation of "rip off" businesses is just being born! Be careful.*" (Microgen forum user, February 2014*)*

As the question of cleaning began emerging and some installers even began factoring annual panel cleaning into their quotes, an increasing concern not just for securing optimum generation became connected to concerns about wasting electricity as an enactment which would compromise maximum benefit. Optimum benefit combined generation and consumption. Waste avoidance however was a complex issue as the following section outlines.

5.6.2 Electricity as Waste

Avoiding waste is complex. Waste has received increasing critical attention in social scientific scholarship in recent years. Of particular interest to this thesis is conceptualisations of waste which consider the performativity of waste both as different categories of material stuff and as categories of judgment (Hawkins 2006) and that investigate how waste is achieved (Gregson 2007, Gregson, Metcalfe et al. 2007, Gregson, Metcalfe et al. 2007). In relation to this conceptualisation of waste, in the field of sustainable consumption scholarship it has been argued that a growing tendency to blame individual consumers for household waste provides a poor conceptualisation of the growing problem of food waste and a poor framework for change (Evans 2011). Evans has usefully considered how food waste is achieved in social practices, which are much larger than a focus on individual consumption appears to reveal. Looking more closely at the organisation of sustainable consumption, he has considered the performativity of notions of thrift and frugality (Evans 2011) in a manner which can help frame the enactments of solar electricity seen so far. Based on a series of qualitative/ethnographic interviews with people who were making efforts to reduce the environmental impact of their consumption, Evans considers the two differently organised social practices of thrift and frugality as two 'ideal types'. Frugality he argues is organised around a moral restraint on levels of consumption, whilst thrift is organised around "Restraint on expenditure that maps onto the moral imperative to preserve household economic resources as an expression of love and devotion towards immediate family and friends"(Evans 2011).

These 'ideal types' are not empirically distinct neither in Evans study nor in the ethnography carried out for this thesis, but they provide a useful way of considering the manner in which people organised their energy consumption in the light of solar electricity. Although notions of frugality were not absent in the everyday enactments of solar electricity described, the dominant framing of energy use was one of thrift. People would strive to use energy differently rather than use less. And as already outlined in the previous section, an important part of a thrifty use of electricity lies in avoiding waste. Wasting electricity was considered bad not just from an economic point of view in that it was a waste of money, but also in relation to the energy system and the environment: inefficient use of electricity was equated with waste, which would ultimately harm the environment. Electricity however was not the only thing, which could be wasted in the enactment of solar. Waste could be unused electricity, but it could also be other things, like money or importantly time. And waste could be achieved and created through calculation and through making divisions between electricity, which was used in the household, and electricity, which was not. As Gregson and Crang (2010: 1027) point out: *"*that which is managed as waste is waste, and that which is waste is managed". Living with solar panels involves a number of enactments in order to avoid waste, but electricity was not the only kind which people were concerned about wasting. The following excerpt from my research diary illustrates the complexity of managing waste in everyday life:

> **(Research Diary, January 2012)** Dan likes detail. He knows how much his system is producing and how much he is using: "*like any good scientist would*. *It's simple. There's no point having a car, a camera or a house unless you know something of its workings"*. He despairs when young people these days waste things, like energy, just by not paying attention. *"These people never check their receipts at the Supermarket and never shop wisely, always in a hurry to fill the basket and move on. They leave food in the fridge until it begins to change colour. The same people leave the lights on, sometimes all day; they take prolonged showers, sitting for ages in the tray, running the hot tap when they're in the bath. They have the central heating on all day and windows open. People have forgotten what sweaters are really for; and doors to rooms; and thick curtains in winter. NOT us".* So Dan takes care not to waste electricity, just like he takes the time to check the receipt at Tesco, to make sure that the offers and 'buy one get one frees have gone through properly. If they haven't he stands in line at the

customer services to get a refund. He considers this time well spent. Dan is in other words a very 'rational consumer': given the right information, provided with the right numbers, he will do the economically sound thing. But when I ask about making changes to the time of day he does certain things in the house, to make the most of the power from the panels, the money suddenly seems to lose power: *"We don't think its worth changing the habits of a lifetime for the sake of a few quid!".* Electricity and money are not the only things you can waste, you can waste time. Dan weighs up the different kinds of potential waste by doing the sums: *"My neighbour lives alone, is very frugal with usage, taking care not to use too much power in darkness - she earns an additional £76 a year in export. We do no such things and get about £54 at export rate.*

Life should be governed by common sense and pleasures, not energy consumption".[7]

The notion that 'life is too short to be too frugal about energy consumption' was often mentioned during my visits. Questions about what electricity 'well spent' or 'wasted' might be were therefore not fixed but relational. Establishing whether electricity was being wasted or not was therefore a complicated matter. As I visited the households after a year of living with solar, the question of what kind of change had happened as a result of solar electricity now being a part of everyday life was difficult to quantify. As the majority of householders had put more thought than usual into external impacts on energy consumption, many of them had begun unpacking the notion of 'a year' as a

[7] It needs to be pointed out here that Dan's calculation here rests on a misunderstanding of how export payments work. As export is not in fact metered but rather deemed at 50% his neighbor's larger export payment relates to her generation, not her consumption. Her frugality in electricity usage after dark would potentially show up as a reduction on her utility bills, but will not impact her Feed-in Tariff payments.

comparable entity. Having begun to notice how both generation and consumption is seasonal: how cloudy weather increases the need for light inside the house (often mentioned as a particularly frustrating correlation for people with solar electricity) and as time went on, how the generation pattern could be very different in the same month in two different years, it became clear that the 'neutral' and quantitative category of a year's energy consumption, was a very problematic entity for comparison, making it difficult to see exactly what kind of change to electricity bills solar was responsible for.

The largest drop in energy consumption of all households was a reduction from an annual electricity use of 8186 kWh, to an annual use of 4548 kWh in Matt and Eve's house. This is a very big reduction, and unlike the kind of reduction I saw in other households. Looking more closely at the year however, not in terms of energy but in terms of other things happening in the household, this was the year that their teenage son went to university. So the household changed from being 3 people to only 2. Simultaneously Matt had now begun paying much more attention to the local weather and its impact on both generation and consumption. So whilst Matt and Eve had changed a number of energy uses, and were delighted about their smaller electricity bill, they were unsure about who or what caused how great a reduction and would speculate about how much they would have reduced their consumption if there had still been an 18 year old boy living in the house. Having begun to consider how much weather impacted on not just solar generation but also uses of energy, he also wondered what the weather had been like in the two years compared. Looking at his collection of spreadsheets and energy bills, Matt thus began to wonder if two different 'energy-years', understood in this way, were actually straightforward comparable entities – or whether he was comparing consumption or clouds.

Whilst Matt and Eve had experienced a great reduction in their consumption, Phil and Veronica had seen a rise, not really knowing how to make sense of this:

> "I don't know why that is. I thought we had been using less, and we have certainly thought more about it. I suppose we have probably got some new appliances, like a new TV and I don't know if the kids use more gadgets now, but I would have thought our consumption would have gone down" (Veronica, householder, September 2013)

Importantly, for Phil and Veronica, this is not a case of complacency or indifference. They were among the households who initially stated that their motivation for investing in solar was to a large extent because they wanted to *'do the right thing for the environment'*; they also spend a bit extra money on electricity in order to use a green energy supplier. The installation of the panels happened as part of a refurbishment and insulation of their second floor, which also came with a number of energy-saving features. As the annual generation figures for their installation were also less than the predicted figure they had been given, Phil and Veronica were somewhat disappointed all round after the first year. And although they still had faith in the technology, thinking that next year would probably be better as it had been a fairly bad year weather-wise, they did not have any way of accounting for what exactly had made their consumption go up.

> "*I suppose the workmen will have used a lot of electricity when they were here, but do you think that is it?"* (Veronica, householder, September 2013)

As we spoke about the results a number of things became increasingly unclear: Can you compare an 'energy year' where major renovation work went on with another? Does a newer and more energy efficient, but bigger TV use more or less energy? The question is not trivial: comparing energy consumption on a year by year basis is a frequently used technique for establishing impact of different energy initiatives and technologies such as solar panels (Munzinger, Crick et al. 2006, Watson, Sauter et al. 2006, Keirstead 2007).

But on an individual household basis there was a sense particularly as I visited the households after they had lived through 'a year of solar', that to a certain extent knowing more was knowing less. People had more numerical information, but also more doubt as to exactly what those numbers were a representation of and how much practical use they were in their daily enactments of solar energy.

5.7 Conclusion: Situated Powers – when the house is not the end

This chapter showed how the vibrant agency of solar electricity was involved in assembling a particular situated power: household solar. It first introduced patterns of solar generation and illustrated both the variability of solar on a daily and seasonal basis and the mismatch this presented in relation to average energy consumption patterns. I argued that although the grid-connection of these systems secured continual availability of electricity, the temporality and intermittency of solar electricity inside the home was performative and presented a particular challenge for householders: that of using electricity when it was available as opposed to when it was needed or customarily used. I argued that the material properties of solar arranged as 'portions of power' further encouraged an enactment of 'using up', causing unused electricity to be seen as excess or surplus power.

I then showed how people responded not merely to the financial and political arrangements of solar through the FIT, but to the situated power of solar. Increased opportunities to monitor and visualize flows of electricity did not provide people with straightforward guides to action, but rather introduced complexities and made visible how vibrant a materiality even 'domesticated' solar electricity is. Rather than develop managerial control over flows of electricity PV users developed a particular experiential knowledge of solar in the households through efforts of keeping track of and using solar electricity up. These enactments shaped both the process though which people came to know and be with solar electricity and the flows of power to certain devices (and not others) and ultimately in and out of the household. I emphasized how this enactment was not merely a calculative interest in maximizing financial output but rather a qualculative enactment in which both financial interests, environmental concerns, values and practicalities in relation to the organization of everyday life and the material agency of devices and the properties and propensities of solar electricity and weather were assembled.

Particularly two categories of household appliances and devices were affected by solar: battery-driven devices such as mobile phones, laptops and electric toothbrushes, and white goods involved in washing and drying of clothes and dishes. I argued that whilst solar did not have the power to fundamentally challenge broader social practices or overall levels of household consumption in the households visited, it did lead to enactments of tuning and adjustment in relation to specific material flows of power.

I argued that the material agency of solar electricity as an intermittent, limited power which flowed not only into the house but also out of it was integral to an understanding of a particular enactment of solar electricity, in which exported electricity frequently became enacted as waste and subjected to efforts of thrift and waste prevention. I showed how this was not merely an interpretation of a particular social arrangement of solar electricity (the FIT), but a performative enactment in which flows of electricity which were (partly) visible to householders inside the household whilst invisible as they travelled onwards in the energy system came to shape flows of electricity in ambiguous ways.

The everyday enactment of solar electricity in this chapter has shown how the situated and specific powers of domestic solar performed an ontological politics beyond the intentions in the Feed-in Tariff and micro-generation more widely. It suggests that whilst people do respond to political interventions and use energy as part of wider social practices they do also respond to particular powers. In order to investigate this further and develop a better understanding of how solar comes to be a particular and situated power, this thesis has proposed to employ a diffractive comparison of how solar is assembled differently within the context of rural electrification projects (as outlined in chapters 2 and 3). The following chapter follows this curiosity about how specific powers are not merely distributed in different ways and in different quantities, but *achieved locally*, into an investigation of how solar panels are made to matter in domestic households in rural Sri Lanka.

6 Enacting particular powers - Solar Home Systems in rural Sri Lanka

6.1 Sri Lanka and the relative successes of large scale diffusion

Figure 6-1: Rural household with 2 lightbulb Solar Home System, Galgamuwa, Sri Lanka

In March 2005, Damien Miller, the then Director of Rural Operations for Shell Solar drove from Bibile in the Sri Lankan UVA province to Ampara in the Eastern province. On this journey he saw a lot of solar panels and thought to himself:

> "this is what large-scale diffusion looks like… when every home in sight is using the technology. When one house buys it and has light at night, then neighbours come to see it, talk about it, get convinced and then buy it themselves" (Miller 2011: vii).

The diffusion of Solar Photovoltaic technology in Sri Lanka, according to Miller, was a great success. The success criteria here was numbers of Solar Home Systems sold in comparison to other emerging solar markets, and in 2010 Sri Lanka looked like the epicentre for solar power in South Asia (Miller 2011). This success criteria was also what enabled the model for solar diffusion in Sri Lanka to become a formula for future World Bank projects in countries such as Bangladesh and China (Miller 2011).

In March 2012, I drive down the same road, the B527 from Bibile to Ampara. As we get close to the village of Galgamuwa I, like Damien Miller 6 years earlier, am very excited to see lots of little solar panels sticking up from almost every little hut I can see from the street. Unlike Damien Miller, I have time to stop and spend the day talking to people in the village. I learn that the 226 solar panels in the area were installed in 2004, through a Donor-project paid for by the Indian Government. Almost two thirds of the 2 lightbulb systems still work, as do 10 of the 52 street lights (see figure 6.2). What it means for them to work is somewhat fluid it appears, but as they were free, except for the car batteries they themselves had to replace after a number of years, the villagers whose systems work are mostly happy with them. They do blame them however for the fact that their remote village always seems to be by-passed, whenever there is talk of grid expansion in nearby areas. As I leave the village that evening, having learnt a great deal about what a 2 lightbulb system does or does not afford in terms of light or other services, I think to myself: This is what exclusive focus on diffusion looks like, when the main success criteria for solar panels is their ability to be sold in large numbers. There's a problem here however: A large number of very small solar panels it appears is not necessarily the same as a well-lit village full of happy electricity consumers. As the friendly people of Galgamuwa told me; *"you had better go now, before it gets dark".*

Figure 6-2: Solar Street lamp with lamp, panel and battery removed, Galgamuwa, Sri Lanka

In this chapter I investigate the emergence of situated powers of solar panels in Sri Lanka, particularly solar panels which were part of the Solar Home Systems distributed by the RERED project as outlined in chapter 3. I question how these solar panels were made to matter: what they could or could not do in domestic homes in rural villages in Sri Lanka. This is a curiosity, which differs from the literatures mentioned in section 2.1.3, which investigate barriers for diffusion or grapple with the thorny question of whether SHSs are an appropriate technology for development. This thesis considers the journey solar panels have to travel to get to rural households to be an important part of their material agency once they are in place (Akrich 1994, De Laet and Mol 2000), but its main curiosity is not diffusion but everyday use. The solar panels in this chapter are already installed and as such they act. They do something and that something participates in shaping and making possible certain worlds. The question for this chapter then is what kind of situated power emerges through the everyday enactments of Solar Home Systems in rural villages in Sri Lanka.

The chapter proceeds as follows: Section 6.2 considers solar as a multiple power in Sri Lanka in two sub-sections: sub-section 6.2.1 begins by outlining what kind of power SHSs promised to be as they were installed and became part of households in rural Sri Lanka. Sub-section 6.2.2 then describes which devices they powered for how long and what kind of material presence they were in everyday life. In section 6.3 the chapter moves onto an investigation of the manner in which people came to know and be with or develop experiential knowledge of this material agency through everyday enactments of portions of power (6.3.1) to be budgeted (6.3.2), used up (6.3.3) and backed up (6.3.4) and outlines what kind of situated power these enactments achieve (6.3.5). Section 6.4 then briefly considers the affordance of this power in relation to the different power of the grid.

6.2 Enacting the Solar Home System: making multiple powers matter

Figure 6-3: Household with Solar Home System and TV antenna, near Maho, Sri Lanka

The following section outlines what kind of assemblage Solar Home Systems (SHSs) came to operate in in rural Sri Lanka during the Renewable Energy For Rural Electrification (RERED) project. Section 6.2.1 considers firstly what kind of imagined geographies of life in un-electrified places help inform and shape development interventions such as the RERED project and section 6.2.2 further considers how the technical and social specificities of SHSs in rural Sri Lanka came to translate into a particular temporary power. Section 6.2.3 introduces SHSs as objects of financial considerations and shows how enactments of repayment impacts on both valuation, use and functioning of SHSs.

6.2.1 The imagined geography of the rural poor

The term rural electrification as deployed in the RERED project carries with it a certain imagined geography (Said 1978) of a place where there is no electricity, where houses are lit by oil lamps or not at all and where people live everyday lives without electric power. This imagined geography is a performative part of efforts to provide electricity to un-electrified places as discussed in section 2.1.3 and exemplified by the manner in which SHSs in Sri Lanka were designed and distributed as detailed in section 4.3. Section 4.3.4 has already begun suggesting that SHSs did not in fact travel to places where there were no powers, but instead to places where particular powers were already in use, powers which had different properties.

The different properties of different kinds of power are important in places like rural Sri Lanka where there is no electricity grid. When I first began visiting villages to talk about 'solar electricity' or 'solar energy' there was some confusion about terminology. I asked about solar electricity, but was corrected: solar was not considered to be 'electricity'. It was simply 'solar'. Electricity was something else. People did not use the term much, but electricity was the grid, or 'the line' as people would call it. There was solar and there was the line. Working with translators I initially put it down to language, culture even (see section 3.5.4), but it soon became clear that this was a very material distinction. From the point of view of everyday affordance or situated power, solar electricity and grid electricity are very different forms of material agency: different technologies, and very different capacities. Thinking about electricity simply in terms of quantity (i.e. solar provides a little, the grid provides a lot) does not provide an adequate picture of what kind of situated power these have. Electricity is always a particular presence; what it does is very dependent on how it comes: solar was not considered as giving "access to electricity", but of providing a particular portion of solar power, or more precisely: it powered particular devices.

Some of these devices were already there. Although known by different names, electricity was already at work in these un-electrified households: as alkaline batteries powering lanterns and stereos and as car batteries used to run black and white TVs, larger stereos, cd players and mobile phone chargers. Just like villagers in rural Sri Lanka did not use the term 'electricity' to refer to solar, they did not consider batteries to be electricity either, just like the imagined geography of un-electrified rural villages mentioned above most often does not. So in other words, a lot of the TVs, which I had been told rural villagers, wanted, they already had. A RERED customer satisfaction survey revealed that 78% of the households who purchased an SHS had previously been running black and white TVs off car batteries (ACNielsen 2006). Villagers in rural Sri Lanka, I soon learned, ran lots of things on car batteries. People living in rural villages most often don't own cars, but they frequently own car batteries. These are taken to be charged at a charging shop in the nearest town or along the main road, at a cost of approximately 50 – 100 rupees (20-40 pence) every time. This cost is covered either by the individual households or by a number of households in the village all getting together for example to watch a movie in the evening. Understanding this particular battery-practice explained not just the disproportionate amount of roadside shops selling car batteries in a country where relatively few people own cars, but also some of the issues why solar often failed to make that much of an impact as a capacity to alter everyday life. The majority of people who bought SHSs already had some experience of using electrically powered devices. Sri Lankan advisor to the World Bank, Anil Cabraal explained to me how this was one of the particular challenges SHSs faced in Sri Lanka:

> *"The Solar Home Systems provided electricity for the slightly better off. The poor people couldn't afford it. But people often forget that not everyone who lives in rural areas is very poor. The people who bought Solar Home Systems had a little bit of money. A lot of them already had a TV. So they were more demanding customers, they were not happy with what solar could do*" (Cabraal, Solar advisor, January 2012).

My conversation with Bandula Chandrasekara at the Energy Forum in Colombo elaborated on this problem of a global imagination of rural villagers which provides a poor understanding of the material domestic arrangements of the 'differently rural' in Sri Lanka and other places:

> *"People often think that a mud hut is a mud hut. But there is a big difference between mud huts here and in Bangladesh or in rural India. They are made of mud yes, but they are not the same size, houses in Sri Lanka are bigger. So when I was approached by this guy from Lighting Africa about solar LED lighting systems I said that it won't work: it might work for reading but houses in Sri Lanka are too big for it to light up the house"* (Bandula, Energy Forum, March 2012).

As the vignette at the beginning of this chapter also shows, a large number of panels distributed through the RERED project had not led to a well lit Sri Lankan countryside in any straightforward manner. In the beginning of 2012 there were not as many functioning Solar Home Systems about as the amount of systems sold during the project suggested. As I began investigating the whereabouts and powers of all those Solar Home Systems which were sold over the 10 years this project ran they very quickly became ambiguous devices which had resulted in many things at different times and places, but reliable and lasting access to electricity it appeared was not one of them.

6.2.2 A temporary power

A particular property of solar panels packaged as Solar Home Systems in Sri Lanka became dominant from the very beginning: their powers didn't last long. Their particular 'rural electrification' was temporary. As already mentioned in the methods chapter this early finding derailed the investigation somewhat at the beginning of the ethnography quite simply because there were not as many functioning SHSs around as anticipated and finding them therefore required a lot more effort. The absence of SHSs also caused delay because I ended up spending a lot of time investigating the absent panels themselves: questioning what had made SHSs such a temporary technology (Latour 1996). But SHSs were not a failure in the sense that they had never worked in the first place, this was not a story about a failed technological project (Law 2002). Solar Home Systems do work (some of the time), they do enable (some) people to do things they could not do before, and they do make (some) people happy with their purchase. But they also do fail (sometimes) and they do cause (some) people who were already vulnerable to experience increased economic hardship.

These failures are well known in the literature on SHSs, where issues of infrastructure, maintenance and financing have been raised as long as SHSs have been distributed in rural electrification projects (Nieuwenhout, Van Dijk et al. 2001, Cabraal 2012) and this is also what the RERED project itself and the World Bank did in their evaluations: they considered the impact of grid expansion, or (lack of) market regulations, of the particular ways in which repair and maintenance (again often lack of) were organised and the way micro-finance was arranged (WB 2012). This is neither wrong nor strange. These are issues, which have been known to lead to the failure of many of these projects. But something is often missing in these accounts, namely the material agency of SHSs, the workings of the SHSs in everyday life. The evaluations become about diffusion, about whether or not SHS were successfully distributed and maintained rather than about what they afforded, which worlds they made possible: what their material powers were.

Attending more closely instead to their everyday enactment after installation, particularly the manner SHSs came to matter in particular ways in everyday domestic life, involves a different curiosity about SHSs, namely one which questions what kind of power it was when it did work: what it powered and when? From the point of view of daily life it doesn't make as much sense to distinguish between what are external and what are internal reasons for why it doesn't work. But the fact that it perhaps does not work as technologies are supposed to at a particular point in time and space does not mean that it does not have agency, that it does not partake in the building of particular worlds and not others. A malfunctioning SHS might not have the kind of power that an engineer would be interested in, but in this thesis it is involved in the shaping of particular worlds and not others. That is also a powerful thing to do.

The power of solar in Sri Lanka was multiple and sometimes surprising. Sometimes some of the systems worked well, sometimes they did not. But working or not working they were a material-discursive force, which was active in complex and ambiguous ways, which this chapter seeks to follow. The following section investigates the manner in which solar became powerful in certain situations due to its enactment as or enrolment of money, or its power to translate and order money in particular ways. In Sri Lanka as in the UK the power of solar panels to intra-act with money in particular ways, is something, which it is important to unpack in order to understand how living with solar power is living with not just one but multiple powers.

6.2.3 Enactments of paying back: the *other* power of solar

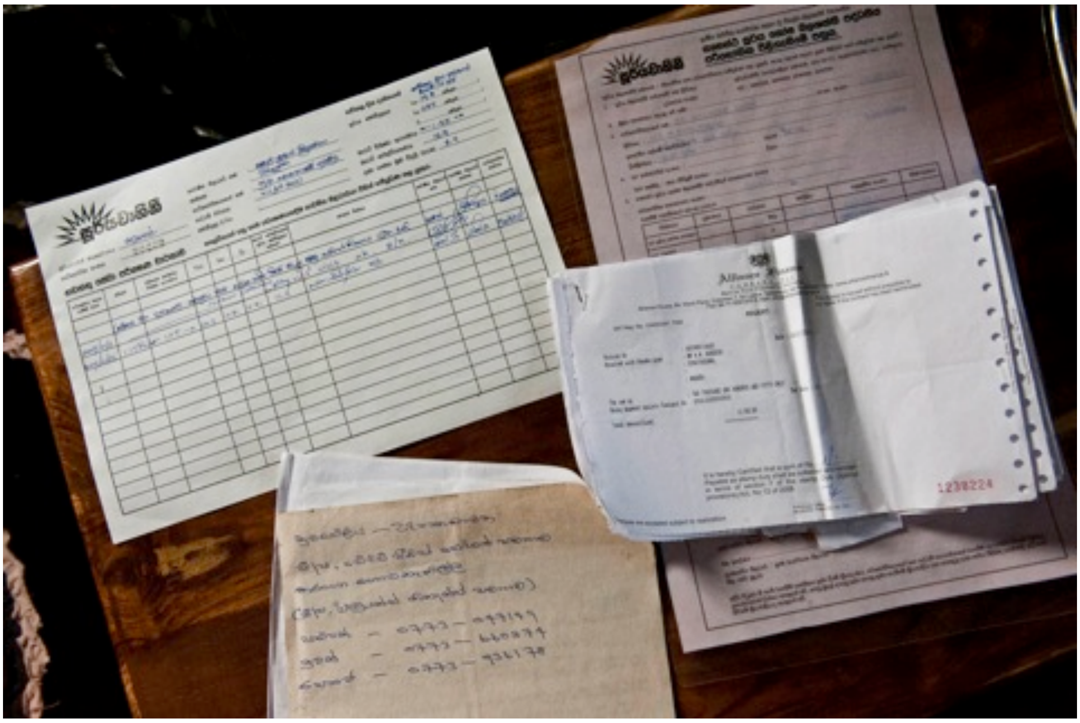

Figure 6-4: Repayment schedule and receipts from Quick's installation, Nuwara Eliya, Sri Lanka

It is useful to reiterate the argument in the previous chapter about how solar was enacted as numbers and in relation to potential financial gains. In Sri Lanka of course finance worked the opposite way to the UK: on a monthly basis solar panels did not bring money in, they took money away through repayments of the loans. Whilst this situation did not assemble the same kind of monitoring network, which it did in the UK, solar panels were still made to matter in relation to money, their performance was still considered in terms of what was being paid and what was considered 'value for money'. Money however, as Viviana Zelizer has shown is not singular but has social meaning (Zelizer 1997), so just as the intra-action with FIT and savings on electricity bills had ambiguous outcomes in the UK, establishing straightforward relationships between money and solar power in Sri Lanka was not easily done. But it is difficult to understand solar panels without attending to their enactments as credit agreements and "money meaningfully spent".

What solar panels were able to do was at no point external to their pricing. We have already seen how pricing dictated their nominal power. Of course pricing also impacted on the expectation people had of the technology. A 20 watt solar panel is not a singular entity irrespective of "packaging", particularly a failing solar panel which was bought for 65.000 rupees is not the same as one which cost 100.000 rupees. It might be the same affordance in terms of nominal power, but it is not the same risk and it is not the same potential to cause economic hardship. SHSs are more than technical devices, they are also investments and their material politics in Sri Lanka did not just consist of being more or less good at providing electricity. They contributed to the building of other worlds too and looking at the manner in which they were sold by installers and paid for by customers helps illustrate this.

With finance from the outset being expected to be a major barrier, the technical system was designed with this in mind: the question of *how much power is needed?* determined by estimates of *how much cost can be afforded?* as outlined in Chapter 4 (see also Laufer and Schafer 2011). SHSs were always a device to be paid for, before a device to generate electricity. Finance was a barrier in the ESD project which came before the RERED just as it has been in many other similar projects (Nieuwenhout, Van Dijk et al. 2001), and was given much consideration at the beginning of the project as the participation of microfinance institutions was crucial to the project. The RERED project was designed as a 'two hand model' in a manner where a technical company was responsible for sales and maintenance, whilst financing was the responsibility of Microfinance Institutions. The installer would sell the SHS, help the user apply for microfinance and then pass the application on to one of the microfinance providers. The microfinance provider would then pay the installer the full amount leaving them out of the repayment arrangements.

As the project went on and systems began malfunctioning for various reasons or people were not able to keep up the loan repayments, the microfinance institutions were therefore the ones suffering the consequences of defaults, whilst malfunctioning systems had very little impact on the installers at least to begin with. Installers were much more mobile than microfinance institutions and would move to new geographical areas once a particular area had reached a certain market saturation. This meant partly that they were able to 'start fresh' in new areas and benefit from much easier sales situations, and partly that they would often be gone by the time systems started to malfunction (Laufer and Schafer 2011, Palit 2013). Many SHS owners explained to me that when problems started to happen they could no longer locate the company, which had installed the SHS: they had vacated their premises leaving behind no means of contacting them. After a few years the two hand model was looking less solid with one hand reaping all the benefits and the other suffering the consequences. As the RERED project matured the installers grew bolder in their sales tactics whilst the microfinance institutions eventually began pulling out from 2008 onwards.

Defaulted re-payments and repossessions are a well-known phenomenon in projects of this kind (Nieuwenhout, Van Dijk et al. 2001). It is often described as a relatively straightforward issue of poor people struggling to pay for expensive devices. This explanation leaves out the material agency of the technology and was not the explanation I was given by the SHS owners I met. Although these people were not affluent, the decisions to stop repayments were not made solely on financial grounds, often people could have paid had they chosen to. Instead missed payments were about malfunctioning technology and about technology which did not live up to the 'value for money' scenario which had made people buy them in the first place. The respective powers of energy, technology and money in daily life were entwined in complex ways, as the following vignette shows:

Figure 6-5: Tuktuk on rural dirt tracks near Nuwara Eliya, Sri Lanka

(Research Diary, May 2012) It's been about half an hour since we took off from Nuwara Eliya in Lucky's tuktuk (figure 6-5), me holding the note with the names of villages, which I got from Energy Forum. Energy Forum went here as part of the *'Physical Verification of Assets'* survey, they did for the RERED project a few years ago. Solar panels and other components travel in Sri Lanka, and the aim of the research was to establish the extent to which systems that had been sold to people were still to be found and whether or not they were working. As I myself become involved in the politics of paying for solar panels on this visit, the survey categories *'Couldn't locate the house', 'no one was at home', 'system is installed at a different place', or 'system has been removed by PCI [*Participating Credit Institutions]' (Energy Forum 2011) which had seemed peculiar when I was first given the report, begin to make perfect sense. These are slippery devices. Nuwara Eliya is in the highlands and receives more rainfall and has more cloud cover than the rest of the country. Because of this the villages in this area were among the later ones to be targeted by the solar installers, as conditions for solar are poorer here than in the lowlands (McEachern and Hanson 2008). They are also very difficult to get to, so they involved greater overheads for the installers.

We have stopped a few times and Lucky has asked for directions and we are pretty sure we are in the right place. But we can't find any panels and nobody seems to know about any. Lucky asks two girls who are walking up a dirt track, but they don't know anything about any solar panels they say. We drive around a bit. The dirt tracks around here are bad even for dirt tracks, and the tuktuk is struggling. The grid, in a rather rudimentary form, has somehow made it to some of these villages it seems, goodness knows how, because even getting here in a tuktuk is almost impossible and we only really see people on foot. Eventually Lucky has managed to find somebody who knows about a solar panel. His name is 'Quick' and he lives further up the hill in the little hamlet. So we move on trying to find him. As we get closer to a little area with a few houses, we catch up with the two girls again. They look at me inquisitively before they eventually point us in the direction of Quick's house. It appears they live next door. I'm puzzled by why they said they didn't know anything about panels, when their neighbour has one. *"I think maybe they thought you were from the Bank or something"* Lucky says and laughs. After we have spent some time talking and having tea with Quick and his family, and word has got out that I am not from the Bank and not here to get anybody in trouble, things change. *"There used to be lots of panels here"'* says Quick "*but the bank came and took them all. There were maybe 50 panels in this whole area, but now it's only about 3. That's why people* *didn't tell you, they don't know if one day the Bank comes and asks for money. You should talk to Mrs Ranasinghe she is a very angry woman, they lost a lot of money!"*

The price people paid for systems, and with that the risk to their livelihoods varied greatly throughout the project and in this particular area they were sold at a premium. To compare, the 5 lights system which Heshani in the Kurunegala province bought in 2004, cost 45000 rupees (£215) which is consistent with the official information from RERED. That figure however omits the cost of financing which in Heshani's case added 20.000 rupees, making the cost a total of 65.000 rupees. But when the Ranasinghe family in Nuwara Eliya bought a similarly sized system in 2009, the price was 80.000 rupees which with the microfinance loan would have taken the total to over 100.000 rupees (£480) or just over two thirds of the household's annual income. As this system turned out to be malfunctioning after a year and no-one was willing to repair it the family stopped paying their instalments on the loan, resulting in the Bank eventually removing the system, which by that time the family had paid almost 60.000 rupees for. Although systems being removed by the bank were a fairly common occurrence throughout the project, this area in Nuwara Eliya was particularly hard hit by this. By 2009, selling solar was becoming increasingly difficult. Sales representatives were not paid a lot but had been able to earn a good living on their commissions. Whilst this made some of the previous installers I spoke to look for jobs elsewhere, others found ways to supplement their basic salary, as Arun from the Solar Association explained:

"A lot of the people who got the loans, couldn't actually afford to pay the instalments. But the salespeople got a bonus for every system they sold, and when the market slowed down, they had to become cleverer to sell enough. So in some places they would make a deal with the person from the Bank who approved the loan: the salesperson would give him 50% of his bonus to approve the loan. So they

> *both got paid and the loan got approved, but the people didn't have the money. So a lot of systems went back to the bank*." (Arun, Solar Association, March 2012)

As the overheads increased and this cost was added to the total price of the system, a negative cycle was created in which the gap between the imagined power of SHSs and their situated powers grew larger as did dissatisfaction and 'deliberate defaulting': the kind of defaulting which was not necessarily the result of people not having enough money to pay instalments. Instead the payments were re-evaluated in the light of discrepancy between imagined and situated performance and the cost of repayment. At the time when the Ranasinghe family stopped paying for their system it was increasingly clear to people in the village that there wasn't going to be any repairs or replacements of parts and that the only way of renegotiating the repayment on a loan for something that was no longer considered worth the money, was to cut their losses and wait for grid expansion:

> *"At that time a lot of people would make sure they weren't in. The man who collected the money, he was from the Bank, and he hadn't been trained, he didn't know about solar. So what one man in the village did was he disconnected the panel from the battery and then he said that it wasn't working, so he didn't want to pay. So they had to send someone out, but that took at very long time, because the company had moved, and in the meantime more people had stopped paying too. It was a mess. We only had a short time left to pay, and then I could sell the panel so we paid it, but that man from the Bank, he never came back"* (Quick, SHS owner, May 2012)

So for the majority of people I spoke to non-payment were not poverty issue, it was not a matter of not having the money to pay, it was a calculative enactment. Although they did not have the kind of ROI calculations users in the UK had, they were still evaluating the material capacity of the SHS on a daily basis. Solar electricity was a material capacity, but despite the absence of financial instruments like the Feed-in Tariff, it was still an investment in Sri Lanka. It was enacted differently as such: evaluating performance with a set of calculations and monitoring devices is one thing; evaluating performance in the absence of a clearly defined expectation is something else. In order to better understand what kind of situated power SHSs provided and what 'doing without' would indeed be doing without, the next section investigates everyday enactments of living with solar.

6.3 Solar Home Systems in everyday life

This section focuses on everyday enactments of solar power: on how SHSs acted, were engaged with and made to matter in daily life. Section 6.3.1 illustrates the presence of solar as a portion of power, whilst section 6.3.2 explores the manner in which SHS owners would budget this power. Section 6.3.3 outlines ways of keeping track and using up powers, and sections 6.3.4 looks at enactments of stretching and backing up, whilst section 6.3.4 summarises the kind of power solar became in these enactments.

6.3.1 Portions of power

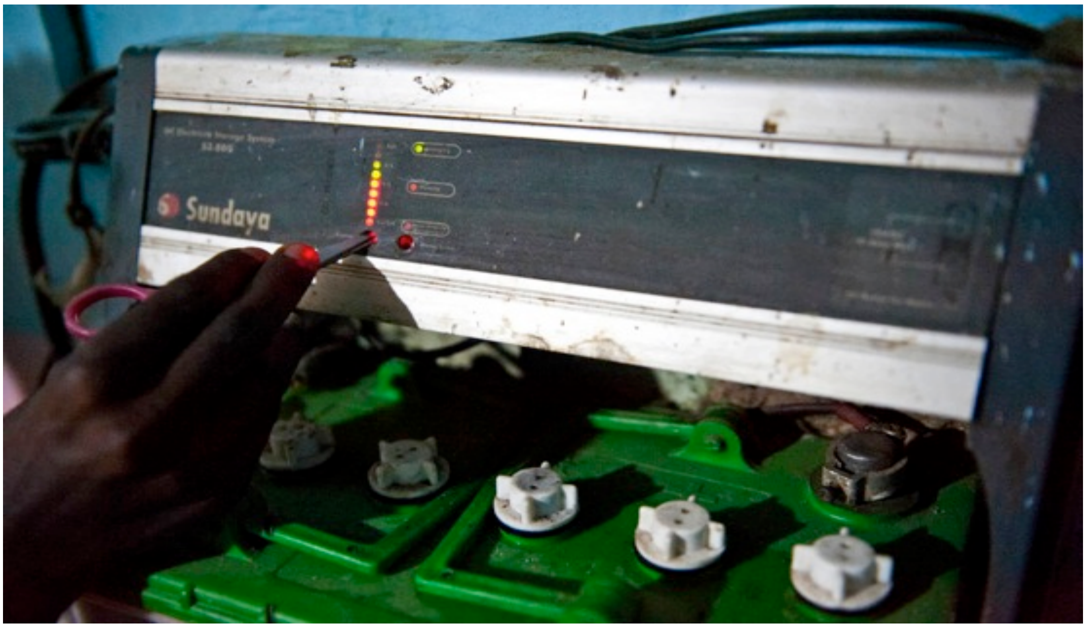

Figure 6-6: Charge controller with traffic light style guide to amount of charge in battery

(Research Diary, April 2012)

"You can see here how much power is left," says Kamal and sticks a pair of scissors into a hole in the charge controller (figure 6-6) where presumably once was a button. A row of red and green lights come on. It's about 4pm and we are just two green dots away from the red. *"It still works when it's in the red, it just means that you probably won't have any power in the morning, or maybe the lights won't work all night. If you want it fully charged, you can't use anything during the day".* This is all part of the daily budgeting involved in living with solar power: *"we use kerosene lamps when the lights don't work... the TV and the stereo use up most of the power, so then we have to use the lamps. Today we have been using the stereo, so we won't have any lights tonight".* The competing appliances in this household are 3 light bulbs, a TV, a Stereo, and a charger for a mobile phone. Compromising and making choices between which services they want to get out of their system is a normal part of everyday life. At first they would often go and check the charge controller to see how the battery was doing, but after a while they developed a certain feel for it. *"we wanted to have a DVD player as well, so then we bought this inverter for 3900 rupees"* He hands the little device to me and it rattles like there are loose bits inside it. *"But this doesn't work?"* I ask. *"No, it broke, and it didn't really work, because you have to plug it in here, at the back, but then all the other things don't work, like the TV! So after that we didn't buy any of the other things we wanted, because we can't power them anyway"*. There are a few households in the little village, which have diesel generators "*they have a bit more money and they don't want solar because it's very unreliable. So we often go there if we want to watch TV". "How do you cope with this unreliability? What do you do if it rains?"* I ask. *"if it rains for a couple of days or maybe 3 days, then we*

have to take the battery down town to have it charged. When it is charged, and if it still rains, it will last for a few days if we don't use it too much. So maybe we only use one of the lights". Kamal explains all of this with a sort of grin that I can never quite get to the bottom of. *"So if you don't use it much, it works quite well?"* I say jokingly. Kamal laughs and nods. I think we understand each other.

Living with solar technology in Kamal's house, as in any other house I visited, was living with car batteries. Whenever I entered a new household, asking about solar technology, this is where I was taken: to the battery. Very few people knew anything about the size or nominal power of their panel; the relevant quantity here was the 12-volt in the battery. In daily use, solar power became translated into battery power. For people who had been using batteries before, the SHSs did enable them to use more power because they didn't have to go take the batteries to the shop to charge them. But this was a difference in practices of charging rather than a different kind of electricity: solar was still battery power. Solar in Sri Lanka then also provided a 'portion of power' in a comparable way to solar in the UK, the management of this power however was different and importantly the manner in which it could be known was different: numbers and graphs were absent here, but people knew exactly which devices it could power and for how long.

6.3.2 Budgeting sunlight: what does it power?

As SHSs were incorporated into the lives of people I came to know in villages in Sri Lanka, this was not a big change from their previous uses of kerosene, small batteries or car batteries. So although it did provide more power, the power was not different in kind, it rarely powered new devices that people had not previously used on a more intermittent basis. The majority were also familiar with grid electricity in some way or another: they knew people who were connected to the line, either because they lived in the nearest town or in a village, which had grid connection. In the light of this the enactment of solar electricity was more a case of 'doing a little more of what we have been doing', so an incremental change rather than a radical one. People enacted solar electricity as battery power only with the difference that the battery would recharge itself every day. Most households had more devices than could be powered at the same time or in the same day or evening. The following excerpt from my research diary introduces a family, which explain their daily enactments of budgeting their powers.

Figure 6-7: Inside Wasantha's house with typical solar powered loads, Galgamuwa, Sri Lanka

> **(Research Diary May 2012)** Wasantha and his wife and two young sons live in Galgamuwa village on the borders of the Gal Oya National Park in the eastern part of the UVA province, where grid electricity is nowhere to be seen and not usually expected to ever expand to. Their nearest neighbouring settlements are inhabited by the Veddhas, who are forest dwellers and this area was considered very remote by all the Sri Lankan people I spoke to. The small roadside shop, which is the centre of the village runs a diesel generator. Like most houses in the village the house which Wasantha's young family live in is a small 1 bedroomed

house, made of mud and with a corrugated metal roof (see figure 6-7). They don't know the capacity of their solar panel in the way people in the UK do: they do not have numbers or the kind of calculations and predictions of generation householders in the UK did. They know its capacity instead as capacity to power certain devices for certain periods of time. It is a small panel. Comparing it to panels I have come across in the last few months I am guessing its 20Wp. The system is the same size as everyone else's, it was donated by the Indian Government through a rural electrification project a few years back and came with two lights, that was all. One lamp is installed in the living room and one in the bedroom. They also have a small TV, a stereo, a small radio, two big loudspeakers and a telephone with an answerphone. Extra wiring has been put in in order to connect the different devices. But a 20Wp panel is not that powerful: there is no way that little panel will power all of this. I ask how they manage to run all those appliances? *"we have to use one at a time, so we don't use them all every day. If we don't use anything else, one light will work almost all night. 2 lights will work for about 3 hours. The TV will work for about 1 hour on a good day. So we watch maybe half of the news and half an hour telly-drama, and then we have to use the kerosene and torches for light that evening* (Wasantha, SHS owner, May 2012)).

Developing experiential knowledge of solar power here involved different enactments to those of householders in the UK illustrated in the previous chapter. Solar power here is not represented in numbers and made visual in graphs. And there is not much need to look at the sun either as the majority of consumption happens after it has gone down. Households in Sri Lanka do not have devices to use during the day unless they watch TV or listen to the stereo. Solar electricity was generated during the day and predominantly used during the night. Whilst generation would not also be the same, leading to different degrees of charge on cloudy days and during the rainy season, on most days being with solar was an enactment of coming to know the material capacity, the extent and reach of this particular power. People had different means of doing so, there were no spreadsheets or meters here, instead people came to know solar as power in time: it translated into one hour of this and half an hour of that. TV uses more power in a shorter time than lights, there is insufficient power to run particular devices simultaneously and so on. Coming to know its affordance and limits was a process of trial and error. Being with solar then involved enactments of household 'budgeting' which this family along with all other families I met engaged in on a daily basis. They all had more devices than they were able to power, so the practice of living with this technology was first and foremost a question of making decisions about what to use the power they had available for, on a daily basis.

Solar was a particular power not only because it was limited, because it could only power some of the devices people had, but also because it powered only particular devices. Whenever I asked people if they were happy with their SHS, if it was working they would say they were, quickly followed by a comment about how it was not the line and how it could not do what the line would do: Solar was not electricity, and they were still waiting for electricity. The RERED project learned this too. Harsha Wickramasinghe at the Sri Lankan Sustainable Energy Authority explained to me how they would get complaints from people who had got used to a certain amount of power and now wanted more:

> *"There was a lot of misuse but of course you have to understand this: once you are given a connection you can't live without it. I have had phone calls from people who were unhappy because the people in the next village were able to use electric irons and they weren't. Once you have it of course you want more, you realise what*

you would be able to do if you had more. So a lot of people were unhappy like that" (Harsha Wickramasinghe, SLSEA, April 2012)

Solar brought a small portion of power, and a small portion of power is difficult to live with. The RERED project officials I spoke to saw this as something to do with electricity proper: that people became hooked and wanted more (as illustrated in the quote above) which the systems were not designed to deliver. Of course the literature on the history of electrification has suggested that increasing demand for electricity has come about historically through a lot of effort on behalf of e.g. retail markets, infrastructures, and different powers (Nye 1998). But for the RERED project solar electricity as situated power was not that kind of distributed achievement, rather SHSs were seen as neutral mediators of a much desired resource and commodity.

What everyday uses of SHS showed however was that solar was not neutral. It was a particular power both in its limited selection of services and in its intermittent presence. Solar power never became inconspicuous or invisible, people were all too aware of when and on what solar electricity was being put to use. So when people I came to know waited for the line it was not merely a wait for more electricity, but for a different kind: one that had the capacity to become considered a resource: an invisible and flexible affordance. Whilst there is no doubt that Nalin Karunetilake's statement that Sri Lankan people wanted TV (in Chapter 3) was true, it was not the whole truth. When speaking particularly to the women in these households they would often be dissatisfied with the technology for not being able to power anything useful or time-saving, such as rice-cookers, spice grinders and irons. As Wasantha's wife explained to me, whilst showing me the many burn marks on her underarms:

> *"its good that we can watch TV, but if we had the line I would get an Iron. They are not that much money. I have to use this one* [she hands me her heavy cast-iron

iron (figure 6-8) to hold] *and it takes a lot of time everyday because I have to first make a fire to light the coconut husks and then put them in and then I iron but the sparks get everywhere and I burn both myself and the clothes almost every day"* (Mrs. Wasantha, SHS owner, May 2012)

Figure 6-8: The cast-iron iron, Galgamuwa, Sri Lanka

The issue here rather than unfulfilled and open ended (cultural) desire for ever more power is about loads. They had been provided with electricity as a resource, but electricity does nothing without a load: solar was a power to power only certain things in certain ways. SHS owners wanted TV because that is what a SHS can power. TVs was one of a few devices or loads it was possible to purchase and which matched the capacity of a SHS. It is technically possible to build an iron, which can run on AC electricity. But you would need a bigger solar panel for one thing and even then it would probably take considerable amount of waiting for it to heat up: electric irons are not a practical or appropriate loads for solar panels unless you add an inverter to the arrangement. The power of electricity is the power of the loads it can run. And just like the situated power of solar in the UK households limited the particular uses of electricity it had impact on, or the loads affected by solar, solar in Sri Lanka affected some practices, but not others. It affected the manner in which people watched TV, listened to Stereos, charged their phones and lit up their rooms. It did not (directly) affect the way they cooked food, or the way they washed and ironed clothes and dishes. Solar was not that kind of power.

6.3.3 Keeping track and using up

In Sri Lanka as well as in the UK then, solar became enacted as a portion of power that needed to be used up. The efforts of budgeting just described were not attempts at saving electricity, but rather attempts of being thrifty with electricity: making the most of it. And doing so involved enactments of coming to know its situated power and enactments of using up this power on a daily basis.

In the everyday lives of the people I met in these villages global warming, climate change or the environment were not matters of concern, and as solar did not make those discursive links it also made no links to ideas about saving electricity. Generally people would aim to use up their daily portion of power, rather than save it. When I asked about leftover electricity at the end of the day I was told that very often there wasn't any, but if there was it was nice because then there would be enough power to have lights on in the morning. One day I asked Roshan if they sometimes tried to save any of the electricity? Roshan looked puzzled at first. So I explained that sometimes at home I would try and not use too much electricity, because it costs a lot of money in the UK. His response highlights the different manners in which solar were not only enrolled in different discourses here, but how it was handled and managed differently and how it became as a result a power, which it would be nonsensical to 'save':

"Its different. There is only a little bit of power and if you don't use it, the battery can't collect anymore new power the next day. Also it doesn't cost money here like in your house. When you buy the solar panel it costs a lot of money and you have to pay a lot of money to the bank, but it doesn't matter how much you use, you pay the same. There is no reason to save power" (Roshan, SHS owner, March 2012).

Shamali explained this in a similar way: *"it's not like the line, where you can do what you want. It is only a little. So we use it all, because the battery is not that big. We can't always watch the whole program... if you have the line, then you can switch it off, because you need to go to bed" (Shamali, SHS owner, March 2012).*

Solar power in this enactment wants to be used. Not only because of absence of climate change discourses or concern for the environment, but because of the way it is being managed and handled. Solar is power on credit, just like anything else you might buy on credit: it is paid for on a monthly basis and the amount you pay is not related to how much you use. The electricity stored in the battery was enacted as a 'daily' (although mainly used during the evening and night) allowance, as Roshan explained above: If you don't use it up, where are you going to put next day's 'harvest'? Once the battery is full, there is nowhere for any further potential power to go. It might make sense to save 'energy' in the UK. But saving 'power' in the villages around Palukadawala, makes no sense: you have to use more to be able to store more. And of course the payments on the micro-finance loan were not connected to the amount of power generated or used.

As mentioned in Chapter 4, the quantity of available power was not known through precise measurement in Sri Lanka, the way it was in the UK. The charge controllers, as the one in Kamal's house had a simple traffic light-style display, which gave an indication of how much power was left in the battery. A good way to illustrate the manner in which these charge controllers related to electricity usage is to compare them to the petrol gauge in a car: Just like the petrol gauge is rarely understood to provide accurate or precise information about how much further the car will go, neither was this. Knowing that it was probably about to run out of power was not going to make people switch the TV off halfway through a program. As was the case with Kamal's charge controller these would work to a fashion, or often not at all after a period of time. In many cases people would re-wire their systems and try to by-pass the charge controller altogether, giving up the ability to monitor the quantity of power, in return for a small saving from not using the charge controller.

Whether the charge controller was in use or not, it was not considered to provide any particularly clear information. It would give you an estimate of charge but this was not information, which could easily be translated into amounts of time using particular devices. Only experience and trial and error could do that. And when it went wrong, when predictions were off, it would most often be the lights which were the least important to run. Shamali who has just had the line installed a month ago is telling me about the arrival of the line and how she can now watch TV without it going off*:*

> *"before when we were watching the TV and the program was not finished and we knew that if it went to here (pointing at red dot on charge controller display) we probably wouldn't have any light. And if it was up here I was just hoping it wouldn't go out before the program ended (she laughs)"* (Shamali, SHS-owner, May 2012).

Solar electricity in Sri Lanka then was not the kind of electricity people could represent in numbers or keep track of in terms of monitoring, as was the case in the UK. And although the case for actually cleaning panels might be more easily determined as these were often installed in dry sandy villages where dust would build up on the panel, this was not a matter of concern or speculation for the SHS-owners I came to know. That did not mean that they did not consider ways in which overall performance could be improved, but they did so in a different way, often following the kind of 'make do and mend' style creative engagement described in the literature with the notion of Jugaad (Jeffrey and Young 2014). The RERED project officials and solar installers would refer to this as people being 'clever', said in a way that clearly marked that they in fact thought they were being the opposite. The following section looks at the ways in which users would try to make the technology do more.

6.3.4 Stretching and backing up

Figure 6-9: Back-up kerosene lamp and spare kerosene in bottle (my iPhone in the picture), near Dambulla, Sri Lanka

The houses I visited in rural Sri Lanka were of varying quality. Some houses were quite large houses built of stone, often over generations, where a new room or floor would be added a little at a time as and when the money was available. What appears to be half built houses is a common feature of both rural and urban landscape in Sri Lanka. The largest houses would often house an extended family. Other houses were very basic mud cladded huts consisting of only two or three rooms, which housed a couple and their children. The RERED project administration had taken this into account in the planning of the project and offered two different sizes of systems, one which they anticipated people in larger houses to buy and a smaller and cheaper size, for people with a lesser income. As the project went on it became clear that the larger system, although a better fit for people's needs, was too expensive to sell. Larger houses with more inhabitants have not necessarily got any more disposable income, than smaller houses with few inhabitants. But they have more rooms to light up. So the majority of customers bought the smaller system and hoped that they would be able to stretch it to suit their needs. Despite the fluidity of the Solar Home System already mentioned, in one rather crucial part of the installation there was less flexibility: the lights, once installed, could not easily be moved between rooms. In comparison to the kerosene people had been using before this was not a flexible fuel. In some houses I visited decisions had been made about which rooms were to have solar powered lights and which rooms were to continue using kerosene lighting. But in most cases a certain amount of experimentation in ways of distributing the power had gone on, with greater or lesser success.

> *"People installed all sorts of things themselves. But the system couldn't power more than 5 lights. The houses needed bigger systems, but people couldn't afford it, so they bought a smaller system, but it didn't match their needs. The small systems couldn't power a TV, but people plugged them in anyway, so the batteries went flat. And if a battery is flat for a couple of weeks, it dies"* (Laksiri, former Shell Solar, April 2012).

This enactment of stretching or overusing batteries was a contested issue. When the installers and project officials spoke about this it was understood as a matter of misuse of the technology; it was people who did not appreciate how the technology worked and behaved recklessly towards it. These people were, it was said, *"just people from the village"* who despite being told about this, still went on and misused the technology. They were deliberately using the batteries in the wrong way.

This was not entirely the way the issue of overuse presented itself when I visited the households where the overuse took place. Here, the overuse was a deliberate attempt to get more out of the system than it was currently delivering. People were not unaware of how batteries worked; most of them had many years of experience of powering devices using batteries. What they did know however was that in the context of household energy use they didn't work very well. Car batteries might be good at powering cars, but they are not very good at storing solar power, and choosing affordability over material capacity had a price: it co-shaped a particular power.

Overusing car batteries was a response to an expensive investment, which did not quite deliver the product it was expected to. It was a creative and (most often) deliberate intervention. It was also an intervention which people used within the context of a tried and tested back-up system. SHSs were not enacted as a stand-alone device; people would call on their experience of living with batteries from before solar, and take their batteries to be charged, when they needed a fully charged battery on a day where available sunlight could not quite deliver that. For a lot of people this would be something they did mainly in the rainy season, where they generally only had enough power to use lights, but not TV or stereo. But even a few days of overcast weather could mean that the capacity dropped below the desired levels. This was not considered a malfunction as such but an inconvenience, which could be remedied by adding a secondary source of power to the technological assemblage of the SHS:

> *"it depends sometimes what we are doing. If my husband is going to work, there is a shop on the way, so he can take the battery with him on the bike. It doesn't cost very much, so if there is no sun for a few days and we haven't got very much power, we do that"* (Hiruni, SHS owner, May 2012)

Absence of sunlight in Sri Lanka created the same need here as it did in the UK: the less sunlight there was, the greater the need was for electricity, so power had to come from elsewhere. There was no electricity-grid in these villages, but there was a different network: all over rural Sri Lanka are roadside shops, which sell and charge car batteries. Just like domestic solar would not be a viable source of power in the UK without grid-connection, this network of charging shops where people could take their batteries when solar electricity could not be generated supported SHSs in everyday life. From the perspective of the installers and the RERED officials I spoke to this was part of the problem of overuse; the batteries couldn't cope with this. From the perspective of the users however this was something which helped make solar more reliable: for electricity to be useful in everyday life, for it to afford the building of routines and habits even change, however small, people need to be able to trust its presence.

Another issue which made the overuse of batteries a sensible solution within the framework of everyday living was the status of solar as a stepping stone technology. Ultimately for most people this was always already a temporary solution. Living with solar was not something people imagined doing for a long time, it was a system which was in place whilst they were waiting for something better:

> *"We could stop using the TV and the stereo and just have lights, but that's not what we want. The battery would last longer that way, but then what's the point of having it? We hope that one day soon the line comes, and it will be cheaper and*

> *better and we will not need a battery. But now we just have this*" (Ruckshan, March 2012).

As has become clear, distinctions between rational and irrational battery management were indeed situated and the result of particular frameworks and different experiential knowledges of their properties and propensities. These solar users knew about batteries. They knew perfectly well that using the battery in a particular manner would slowly drain it until a new one would have to be purchased. They were indeed *'just people from the village'* as the installers suggested (above), but being from the village they knew something about living off grid and about the situated power of solar, which the installers did not, something about the everyday usability of solar electricity. There was no information deficit here; instead there were difficult everyday choices.

Whilst the battery could be charged in order to power the TV and stereo, light had a different backup system of kerosene lamps. The preference for using the solar power on TV over lights had a lot to do with this. TV was not as such more important to people than light, but kerosene is a much more flexible backup power. It can be bought in larger quantities and kept in the house for situations where lights go out and even failing that there is always a small shop or a neighbour who has a bit of extra kerosene in an emergency. Kerosene was seen as an inferior and backwards kind of fuel by solar installers and RERED project officials I spoke to, and it is of course associated with a number of health risks and hazards. But as a fuel it has the properties of fossil fuels, it can be stored and transported and it can adapt to changing demands (Mitchell 2011). There were many similarities in the manner people in rural Sri Lanka spoke to me about kerosene and the manner people in the UK spoke to me about fossil fuels. There were many problems with kerosene, people knew of the dangers with it, the light it provided was mostly inferior to the light solar provided, but it was reliable and it was flexible and that made it useful. Solar was there when it was there, kerosene was there when it was needed. The transition from kerosene to solar was not a straightforward improvement. And the only fuel people could imagine would replace kerosene completely was a fuel with similar properties. So they waited for the line.

The rapid grid expansion in the period was an important factor in the emergence of particular uses of and temporality of SHSs, but it is important to consider this materially. Talking to people in the villages the line was not merely a metaphor for western modernity and commodities, it was a useful power: the kind of power you can trust to not just switch, but *keep* the lights on. Wanting to have the line was not primarily a matter of wanting a large quantity of power, but rather of wanting the power that they did have to be a more stable and reliable affordance.

In many of the villages I visited the line had either just come or the villagers were almost sure it was coming within a few months. So many systems were running on batteries, which were almost dead, batteries, which it made no sense to replace. Money would have to be spent on the connection to the line and perhaps new devices which could be powered with 'line electricity'. The monthly cost of paying for electricity was rarely a concern. Despite enabling people to use a lot more electricity than with solar, the majority of the potential new users would become users of the so-called lifeline tariff and therefore not pay very much for their electricity.[8] For people who had been re-paying microfinance loans on solar, the transition to grid electricity included a saving. Microfinance institutions lost a lot of money like that: people did not continue paying more for solar when they could pay less for the line. And after the microfinance

[8] Electricity tariffs in Sri Lanka are priced so that the low end users pay a very small amount for their electricity whilst high end users pay a large amount. The lowest tariff bands up to 30 kWhs in a month are referred to as the 'lifeline tariff', which at the time of writing is priced at 3 Rs. Pr kWh (about £ 0.01) with a monthly charge of 37 Rs (about £0.17). http://www.ceb.lk/sub/residence/tariffplan.html

institutions pulled out the few installers who remained in the market were forced to offer buy-back deals:

> *"It was really hard because you could never really know where the line was going to go. The CEB (Ceylon Electricity Board) couldn't tell you because it was a lot about local politics and it was really difficult to tell. And people wouldn't buy unless they had a guarantee that I would take the systems back if the line came within a year. I am not a Bank so I had to be really careful and selling solar on the second hard market is very risky. So I had to stop with the financing and only do cash-sales. So that's why I only work in the North now because people there have some cash and the grid expansion is slower there"* (Herath, Installer, March 2012)

The movements of the line were fickle, but powerful. One moment, like before a local election, it was practically there: Trees were chopped down on one side of the road to make way for the poles to carry it. The next moment, after the election, it might be years away, maybe not at all (and rumours said that the local politician who was elected had used the trees which were chopped down to build something on his own land). The question of how to use the battery or whether to make provisions for its replacement was not a straightforward domestic one, but rather involved a complex political situation. Understanding the situated power of solar requires an understanding of not just the discursive power of the line but also the material differences between an intermittent and a steady source of power.

6.3.5 Watching TV when you can

Figure 6-10: Domestic panels and antenna in terraced houses on a cloudy day, Monoragela, Sri Lanka

In case a replacement battery was needed, a new battery cost around 10.000 rupees (in 2012), which was close to a month's total income in many of the households I visited. It was a difficult decision to make. When I arrived in households where a system was not currently working well and people were considering whether to invest in a new one however, the cost was not often mentioned directly. It was not just a matter of whether the money was there or not, but an enactment of thrift and qualculation (section 5.3.1), in which a number of concerns were negotiated, like how great an improvement to performance would there be, what else that money might be spent on or saved for, and how long it would be before the line would arrive (where was it now, which rumours were circulating, how close to a local election was it being some of the factors to consider). Enactment of qualculation in this context as in the case of PV owners in the UK discussed in Chapter 5, were situated: it was not a straightforward matter of working out what the most efficient way of using the technology would be, but rather what the most *appropriate* use was given the particular local circumstances. An SHS owner who was deliberating whether to buy a new battery as her current one had just stopped working a couple of months before the monsoon was due to begin framed what kind of affordance or investment this was:

> "*Even when we do have the battery we can't watch TV very much in the rainy season, so we are used to just watching TV when we can*" (Heshani, SHS owner, February 2012).

'Watching TV *when you can*' was in many ways a very fitting description of the kind of affordance solar was in rural homes. Solar was a conspicuous power. The manner in which solar came to power or impact the use of certain devices and everyday habits and not others was even more visible in these households with their limited selection of loads and their much more tangible effect: you could see exactly what it was doing. Solar power was an affordance which could be used when it was there, not an affordance people relied on to be there. Furthermore and as was the case in the UK it was an affordance which was there at a time of the day when it was not easily or usefully employed: using solar electricity 'hot' was not any more straightforward in these households than in the UK. In Sri Lanka as in the UK the need for domestic electricity is greatest during non-sunlight hours. Solar power was a power to be used predominantly in the evening, when people were in their houses.

Enacted as such, solar as a power to entertain during the night was not an uncontested presence in village life. Watching TV did not happen in a temporal vacuum or in time, which had not previously been used for something else. It was not a simple addition to village life but also at times a replacement of time, which would have previously been used for something else. Sleeping for example. So in addition to the many accounts of neighbours coming to watch TV in houses with solar, there were also accounts of how this new temporal affordance might be problematic in some situations, as the following excerpt from my research diary shows:

> **(Research diary, March 2012)** We are driving towards the villages around the Kaduruwewa reservoir. Ajith (my translator) knows the tuktuk driver well. They both work in the same ajurvedic clinic. The driver is not really a driver, but an ajurvedic practitioner, but he generally drives the tuktuk at the clinic, and he lives near this village, so Ajith has asked him to take us there. *"It's been a bit of a problem in this village…"* Ajith says. *"There has been some arguments.".* The driver chuckles as he says this and adds comments now and again in Singhalese. *"It makes people lazy. Some of them they sit and watch TV at night and then they don't want to get up to work in the fields in the morning. Because you have to start working at 4am before it gets too hot. But if the people they sit up late and watch TV, they get up too late and they don't work hard"*. The driver adds information in Singhalese again. They both chuckle. *"some of the women become very lazy too, and they want to have a spice grinder. They don't want to grind the spices anymore!"* The capability of solar to interfere with temporalities of everyday life particularly in farming communities like this becomes clear for me even after a few days of living in this place without electricity myself. I have been staying for only a few days in this small hut without electricity, except from a small oil lamp and my torch, and trying to do anything after 6.30pm where the darkness penetrates everything is almost impossible, so I have surrendered and got used to early nights. And when I wake up in the morning at about 5.30am and walk over to Ama's house for my morning tea and pol roti, everybody else has already been up for a long time. A few hours later it is too hot even for the locals to work in the fields and I make my way to the only shop in the area which is connected to (and holds 'the end of') the line and has a fridge for cold drinks and a little

> plastic table in the shade where I can just about string sentences together for my diary. The wisdom of 'extending the hours' where the household has light, and potentially altering the temporality of everyday life, as solar seeks to do, is not a straightforward affordance. No electric power can extend or generate more than 24 hours in a day and people in this village did not just sit idly for decades and wait for electricity. Unlike me people out here do not just go to bed early because there is nothing else to do, but because they need to get up at 4am. You are literally up against the sun, and in the North Western Province at the end of March; the sun is some force to be reckoned with, not just for foreign researchers.

As this excerpt shows, the usefulness of solar electricity is not an a priori attribute and electricity is not just more or less useful only depending on how much of it there is, but also when and how it is there. Solar electricity as an affordance is a particular socio-material achievement, which enrols situated "external circuits" and shapes worlds, which are not just domestic. The investigation of the particular material-discursive power of SHSs as they were achieved in rural Sri Lanka can be usefully illuminated through the different power of the line as it came to households who had previously been using solar, as the following section will show.

6.4 When the line comes – the power of a rice cooker

Figure 6-11: Quick's house showing solar panel and recent grid-connection, Nuwara Eliya, Sri Lanka

(Research Diary, March 2012) Driving through rural Sri Lanka in 2012 provides a clear testament both to the power of grid electrification and to the unpredictability of it. The thought of mapping it has occurred to me, but these places are not on any of the maps I can find and the movements of the line do not seem to follow any geographical logic. Asking Ceylon Electricity Board for some kind of overview of where the grid is and will be will lead nowhere Herath and Arun have advised me: the politics of grid expansion are too complex. Driving around with Isuru the last couple of days I can't seem to make head or tail of why the grid has expanded to some places and not others. It follows along the big Maho road for a while and then it goes across a field and ends up in the village where Roshan lives, but that is further away from the little shop on Maho road where it turns off and it misses out the village just before even though they are closer to the road. And the village we went to yesterday where we had to abandon the tuktuk and walk, it was there! So why not this village? It is not anymore difficult to get to, I'm pretty sure there are more houses.

By 2012 many of the SHSs which were still in use co-existed with the line. Some people used their SHS as a back-up in case of a power cut whilst others would still use their SHS to power certain DC appliances, like their old TV as an extra TV or the particular lights which had come with the SHS when they bought that. The line of course provided AC power, which meant that the power backup was complicated. Solar would continue to power the solar lamps and DC appliances like the black and white TV, but would not be able to power any of the new lights or new AC devices purchased, like kitchen appliances and the new TV. This resulted in these households having a large collection of both DC and AC devices.

Figure 6-12: AC and DC lightbulbs in the bedroom, Nuwara Eliya, Sri Lanka

Understanding what the line enabled people to do in these houses provided important insight into how different properties of electricity matter in daily life. Whilst it was obvious that people who had grid electricity used more power now that they had access to more power, this was not entirely straightforward. The majority of the former SHS users I spoke to were still not using large portions of power and were able to pay less for their electricity now than they had done with solar. This was on the one hand due to the lifeline tariff system mentioned in the previous section, which meant that the price they paid for electricity was low and on the other hand due to the comparison with the re-payments on the solar loans they had previously had. In many households this was a change of more electricity for less money. The following excerpt from my research diary shows how electricity usage had changed in a particular household near Nuwara Eliya, an area where the price of SHS had been at the higher end.

Figure 6-13: After grid electricity came- living room devices, Nuwara Eliya, Sri Lanka

(Research diary May 2012) It's been almost a year since 'Quick' and his family were connected to the line. They still use the solar system a bit, mainly during the day or sometimes when there is a power cut. Quick wants to sell it, but it is difficult because no one wants them anymore. The line has arrived in a large number of villages, so the rest are waiting for it. Besides with all the systems that were removed or didn't work very well, people don't really have much faith in solar around here.

Quick has been telling me about the history of solar in the area: how the prices were very high, how most systems were taken away by the bank because people didn't pay, either because the systems weren't working or because people didn't have enough money. Quick feels proud that he paid all the instalments on his system though. He walked down to Nuwara Eliya to the bank once a month because they didn't want to send someone out to do the collections. Its two hours there and two hours back. So when the news came that the line was coming it did not take Quick long to decide that he would pay for the installation.

I look around in the house. It is very small, built with a mixture of mud and some breezeblocks, with a roof made of corrugated metal over a ceiling made of tarpaulin. About half the space in the front room is taken up by two enormous loudspeakers, along with 3 smaller speakers, a colour TV, a did player and a stereo. I also notice an electric clock, and a telephone with answerphone. *"Can you tell me what it felt like when the line came, what did you do?"* I ask. The whole family smiles as the question is translated by Lucky, the daughter giggles and Quick, smiling from one ear to the other says *"there are just so many things you can do. With solar we couldn't run any of these things, but now we can go out and buy things that we want and just plug them in"*. There is lots of enthusiastic talking between them. *"what did you go out and buy then?'* I ask and again everybody is talking at the same time *"the TV we had before didn't work because it was for solar…"* explains Quick, and in the meantime the son in the house has turned on the stereo and turns up the volume to full blast. An explosion of sound fills the little room, the large loudspeakers make the floor vibrate under my feet and I automatically take a step backwards. You could quite clearly never make this kind of noise with an SHS!

The really big difference however appears to me as I ask what Quick's wife chose to buy. I am shown into the kitchen, where she proudly shows me her rice cooker, kettle and spice grinder (see figure 6-14). These are devices that solar cannot power and the kitchen has been a room that solar has not had much impact on. Solar is 'living-room power'; the line however can power the kitchen too.

Figure 6-14: After grid electricity came - kitchen appliances, Nuwara Eliya, Sri Lanka

At this point however, I am confused. This is a very small, and very poor quality house, yet it is packed full of what I believe to be relatively expensive electrical appliances and although you have to use more than 90 kWh per month before it

> costs much, I'm not quite sure how much daily use of all these devices would add up to. I ask my translator how much money he reckons this family has available on a monthly basis? *"Oh they are poor, he says, not more than 10.000 rupees a month". "So did you buy all this stuff in the last year since electricity came?"* I ask, *"Oh no",* says Quick *" some of it we had for years, some of it we bought when we first heard the line was coming*". In this kitchen, at this moment I fully appreciate the power of electricity being put to work in everyday life, and why people differentiate 'Solar' and 'electricity' and what even a fairly poor rural household is capable of doing with the line. They do have power cuts Quick explains, but these are short and not a big problem for Quick's family who do not rely on devices like fridges or freezers. In that sense they still use electricity in a similar manner to how they did it with their SHS: they don't put too much faith in its presence. *"sometimes we can use solar when there is a power cut, but usually they do not last long so it's not a big problem. We are used to waiting"* says Quick and laughs.

As energy consumption increased and unfolded in these houses where the line had come, people would often begin by replacing the devices they had already been running on solar: a colour TV instead of a black and white TV, a DVD player, a better stereo, better lights in all rooms. But in tandem with this another room became electrified which solar had not been able to power: the kitchen. Electricity is never a neutral affordance, it is a particular kind of power and solar was not a kitchen power. Waiting for the line was not just waiting for more power. After visiting Quick's house I begin to pay attention to the boxes. All of a sudden they seemed to appear everywhere: Rice cookers and DVD players were the most popular. Almost magically powerful in their boxes still, on top of cabinets and in cupboards. They were sitting there, waiting for the line, along with the people who had bought them in anticipation. Solar panels were there in the meantime, but they did not provide a power you could grow with.

Living with solar was then always already living with the line: in its absence, in the complex politics of grid expansion. And in the shops in the nearby town, which sold rice cookers, spice grinders, irons, satellite dishes, computers, microwave ovens, the list goes on. People knew what they could not power, they knew the price of the devices they could not power: in many cases a price which they were able to afford to pay, and which they did pay, hoping that soon they would be able to power them. So when they were evaluating the powers of solar, this availability of different devices had agency. The other power was already there, not as a natural desire for more power, but as devices on sale in the local hardware shop or devices sitting on top of the cupboard, waiting to be put to use.

6.5 Conclusion: everyday powers and situated successes

This chapter has investigated how solar electricity was achieved as a situated power in rural Sri Lanka. In doing so it has moved beyond enquiries of diffusion and questioned what kind of power solar electricity became in domestic homes following installation and how it was enacted in everyday life. It has argued that knowledge of numbers of SHSs sold provides inadequate understanding of what the technology affords individual rural households, particularly over time, and that experiential knowledge of what SHSs can do in everyday life provides a useful alternative account of their multiple powers.

By focusing on everyday enactments rather than diffusion of solar electricity this chapter has shown that the success of Solar System Sales in Sri Lanka had less to do with their material capacity and more to do with the manner in which they were sold. Solar performed well in a market place which was set up in order to support its diffusion across rural Sri Lanka, but it did not perform as convincingly in domestic homes: many systems sold did not equate straightforwardly to many well functioning domestic systems or many happy electricity consumers, particularly over time.

The strength of the RERED project, what enabled it to become considered a good model for solar diffusion was that it provided an environment or network where SHSs could travel without being 'at risk': where everyday enactments after installation were to a large extent external to the success criteria. Damian Miller suggested that solar could not fail because the World Bank needed a success in order to 'green up' its reputation (Miller 2011), which resulted in a particular project design which emphasized support for solar as a product and for the solar industry as the means for the diffusion of the product. This chapter has described this in terms of everyday enactments and suggests that the success of SHSs in Sri Lanka was temporary: that solar did not fail for a while because it was enabled to travel through a network where a lot of effort (some intentional some not) was put into enabling its distribution. It has shown however how this network was successful only insofar as it could consider the situated powers of SHSs external to its success, and that once solar became evaluated on its material performance over time and in relation to other powers, the distinction between success and failure becomes uncertain and ambiguous.

Understanding how everyday capacities of situated SHSs as these were realized and lived with in everyday enactments has foregrounded the indeterminacy of devices such as solar panels and emphasized how this indeterminacy is not merely a question of human interpretation and perspective but the contingent achievement of specific powers. The experiential knowledges of people living with SHSs provide important insights into how unexpected and ambiguous consequences do not just happen because of human beings interfering with technologies in unexpected ways (Wilhite, Shove et al. 2006), but rather they come into being in intra-action with particular vibrant material powers with specific properties (Bennett 2010, Mitchell 2011). This chapter has shown everyday enactments in domestic households which provide useful understandings of the complexities involved in making not merely energy but particularly shaped and sized powers matter in particular places, and provides an alternative metric to one in which a certain quantity of power is considered context independent.

The ethnographic material in this chapter has illustrated how solar electricity became a situated power in domestic homes which powered a particular group of devices, like lights, TVs and stereos, but not other devices like rice cookers, irons and kettles. These connections to some devices and not others along with the material capacity and temporality of solar generation and everyday life shaped solar electricity to become primarily a power to entertain in the evening. The power of solar as everyday affordance was ordered and lived with not merely through the connections it made, but also through the ones it didn't make: like the small kitchen and household appliances and devices like DVD players which were available to buy at local markets but were AC devices which solar could not power. This missing connection to a particular external network had important effect on solar not being considered a 'useful household power' in the manner grid electricity was.

The chapter has thus shown that there is a need to consider the particular properties and situated powers of solar electricity in everyday use as they travel beyond the "spectacle of profitability and potential" (Cross 2012) which is diffusion, and into everyday domestic lives in out of the way places. Considering the power from solar simply as a limited portion of electricity is inadequate because it does not fully understand the manner in which solar is not merely less electricity than fossil fuelled electricity, but rather has different properties and temporalities which enact different material politics than do fossil fuels (Mitchell 2011, Barry 2013).

Having established the importance of greater curiosity about the specificity of situated powers the chapter has further emphasized how these powers were not essential attributes, but contingent achievements: that the power from Solar Home Systems was one of distributed agency. Solar was not a particular power due to its technological design alone, but rather more fluidly due to its connections to material and political external circuits. Solar Home Systems did not stand alone but performed within a network of other powers, some present some absent. When SHSs did work they did not replace existing energy sources such as kerosene and batteries but rather they were able to work because they could enrol them for everyday back-up support. Solar power in Sri Lanka as in the UK co-existed with other powers, which shaped the manner in which it was made to matter as particular powers for particular purposes.

The manner in which SHS users in Sri Lanka compared and contrasted *solar* with *the line* has emphasized the importance of considering local energy needs in relation to properties and temporalities of particular powers: generation patterns of solar power. As questions of what SHSs could power, when and for how long were put in relation to everyday usage the mismatch between the temporality of solar electricity generation and needs for electricity in rural Sri Lanka unveiled a need to better understand not just how much power energy people living in out of the way places need, but also when they need it. It has showed how, in the case of Solar Home Systems, this mismatch led to solar power becoming almost exclusively enacted and used as battery power which affected the capacity and longevity of the whole system as well as their usability and power in everyday life. In order to investigate the potential for solar to respond to both challenges of development and climate change these material politics and the specific material-discursive worlds they enact need to be understood empirically and locally.

In the conclusions I consider how this understanding of firstly solar as a particular kind of power and secondly microgeneration electricity as a distributed and local achievement can contribute to considerations of how solar panels are and could be put to work in specific or different ways and to the manner in which electricity and energy technologies are conceptualised and investigated in academic research.

7 Conclusions

7.1 Assembling solar powers

This thesis provides insights into how energy technologies and electricity act within different assemblages of domestic solar power. It shows how the assemblages that constitute the socio-material capacities of solar power are context-specific and spatialised in diverse ways. The aims of this are firstly to counter a focus on diffusion and social acceptance of solar power, which this thesis argues has been a tendency in social science policy and research, and provide greater understanding of living with solar electricity, and secondly to move the social scientific enquiry of energy away from viewing it as something to be consumed, particularly within households, towards an understanding of its material force as an actant that shapes modes of social ordering.

This chapter begins by summarising (in section 7.2) the main points the thesis travelled through as it moved from conceptual ideas about the agency of solar electricity through different empirical encounters with solar panels in action in homes in the UK and in Sri Lanka. Bringing this together and re-assembling solar across the two empirical assemblages (in section 7.3) it argues that the interferences between the detailed local assemblages enables important understandings of the properties and propensities of solar power and how these are achieved differently and with different outcomes. Section 7.4 draws the findings of the thesis together and demonstrate how these contribute to debates in energy studies and wider debates in human geography. Section 7.5 considers what the policy implications of the findings and analytical approach in the thesis are and section 7.6 suggests avenues for further research.

7.2 Recalling the journey

Chapter 1 outlined the motivation for this thesis as a curiosity about how agencies and concepts of energy, environment and the home come together in everyday life. It set out the aims of the thesis proposing to investigate the material agency of domestic solar photovoltaics and investigate how particular assemblages of solar electricity operate, through an investigation of its different powers at work in daily life in the UK and Sri Lanka.

Chapter 2 proposed that solar panels should be investigated not as a neutral technology or as immutable mobiles, but as devices which 'make electricity in a particular way' and that this thesis would introduce and develop an analytical and methodological approach in order to do so. In the literature to date there has been a tendency to focus on diffusion and uptake of domestic solar both in the UK and in Sri Lanka, while questions of how human beings engage with the technology have been dominated by notions of interpretation, which conceptualize human beings as active and devices and flows of electricity as passive. Chapter 2 therefore explores how solar panels and solar electricity can be given a more active role as actants in the analysis of domestic solar, and argues that a conceptual approach focused around the notion of assemblages (Deleuze and Guattari 1987, Bennett 2005, McFarlane 2011) and the manner in which these become enacted (Mol 2002) in everyday life, presents an opportunity to bring out the agency of solar power in use. The chapter suggests re-casting the home as an analytical plateau from a prime location for consumption and end-use of energy, to a site of intervention, experimentation and material participation, enabling the analysis to better grapple with the messy assemblages of multiple devices, practices, politics, powers, geographies, weather and values being enacted within them. The chapter further argues that attention to interferences, differences and similarities in domestic assemblages of solar in the UK and Sri Lanka can provide insight into how the different properties and propensities of solar come into being and act.

Having established a need for an enquiry to capture the manner in which differently situated solar panels assemble and are assembled into heterogeneous arrangements, Chapter 3 considered how this might be done methodologically. The chapter suggests that an ethnographic approach with a particular focus on non-human agency is useful for an enquiry into assemblages and processes of meaning and matter. The different fields involved in this research were introduced along with the process of doing research in these places. The chapter suggests that ethnographic enquiry of different enactments of solar electricity should be seen as a distributed and collaborative experiment rather than a means of collecting data and provides examples of how ethnographic practices were negotiated and adjusted according to the different settings in this thesis.

Chapter 4 introduced the properties and capacities of solar panels as they were employed and encountered in the UK and in Sri Lanka respectively, as rooftop solar and Solar Home Systems. This chapter approached solar electricity *as electricity,* by emphasizing the different material capacities or powers solar panels have and how these are made accountable in different ways. Solar panels only generate electricity when they are connected to an external circuit, which means that the particular socio-technical circuits solar panels are connected to in the UK and Sri Lanka are important to investigate in order to understand what kind of power was achieved in the two places, particularly how they were 'wired up' to become a technology in order to reduce carbon emissions and engender behaviour change in the UK and a technology in order to improve quality of life and bring economic development to rural villages in Sri Lanka. The chapter argues that this was not merely a process of a neutral omnipotent technology being scaled and adjusted according to different political interests and local needs, but also a process through which particular political matters of concerns and local needs became enrolled and framed in accordance with a particular technological innovation and capacity. The chapter illustrates the indeterminacy of solar panels through outlining the different ways in which they are subject to, and also evade measurement and calculation in relation to their properties and performances. The chapter shows the fluidity of both the social and material capacities of solar assemblages and argues that the capacity of solar panels not just in terms of social change but also technically and in terms of reduction to carbon emissions is in-separable to their situated enactment: to what people, things and forces do in everyday life.

Carrying this understanding of solar power forwards, Chapters 5 and 6 question how solar power fared as it became enrolled into assemblages of power in everyday life in households in the north of England and in parts of rural Sri Lanka. Chapter 5 provided insights into the challenges of living with intermittent powers in the UK. It suggests that in order to understand everyday enactments of solar panels, one must understand clouds: that daily and seasonal engagement with solar electricity in UK homes would be inadequately understood without attending to local temporal patterns of solar electricity generation. The chapter showed how patterns of solar generation provide a poor match to average domestic energy consumption patterns and how the mismatch between the two acts as a generative and ambiguous force in daily life: an invitation to *make the most* of the available solar electricity. It became visible in this chapter that being with solar electricity in the home involves a messy assemblage of distributed agencies such as monitoring devices, Feed-in tariffs, clouds, seasons, electricity meters and a number of devices and appliances to name but some. In this assemblage living with solar power was not merely a careful orchestration of supply and demand, but also encompassed ways of being with weather, money, flows of electricity and time in ways that made the notion of electricity consumption inadequate. The chapter thus suggests that in these everyday enactments solar becomes a particular power: a power to do certain things (power certain loads) at certain times and not others. As the households in this ethnography developed greater experiential knowledge of patterns of generation and patterns of consumption over the first year, a particular kind of electricity emerged which people knew as *surplus energy*. This, the chapter argues, was not simply a straightforward human interpretation of or response to the manner in which electricity was valued by the Feed-in Tariffs, but rather an achievement of the assemblage with its heterogeneous agencies, like meters, clouds, monitors and values. Solar electricity as it was assembled in households in the north of England wanted to be used up. It was not used carelessly or unknowingly in everyday life, but deliberately to the extent everyday life enabled. The chapter showed that whilst solar assemblages did indeed have the capacity to shift certain enactments and socio-material orderings in everyday life, such as encourage householders to use particular portions of electricity at different times, these changes were often ambiguous and with unclear and unintended consequences. It argues that such unintended consequences should be seen as an achievement of the assemblage rather than as a result of human agency alone.

Chapter 6 turned to assemblages of solar power in rural Sri Lanka. The chapter illustrated the multiplicity of solar assemblages by showing how different enactments and different success criteria existed around Solar Home Systems (SHS) used in un-electrified rural areas. The chapter firstly presented enactments of SHSs in efforts to bring electricity to out of the way places through a particular market-based model which focused on diffusion, which enabled large numbers of solar panels to travel to rural households. Secondly it showed how the dominant success criteria in this enactment: the diffusion of as many SHSs as possible, provided a poor indication of success from the point of view of everyday enactment in rural households and that solar panels in Sri Lanka had performed more convincingly as products in a marketplace than they had done afterwards as situated powers in everyday lives. Through the ethnographic enquiry into living with solar power in these households, the chapter showed how solar power in un-electrified households in Sri Lanka was a temporary power whilst villagers waited for grid extension. The chapter further showed how a majority of the households which invested in SHSs had already been using car batteries to power TVs and stereos and that whilst SHSs provided new powers to the household these did not replace but came to co-exist with other fuels such as kerosene and disposable batteries, and that in periods of bad weather where solar failed to charge the batteries people would take them out to be charged elsewhere. The chapter showed that in this assemblage solar was a power with particular properties and temporalities and that it was enacted also here as a portion of power which needed to be used up on a daily basis and that it was predominantly a power in order to entertain. The chapter suggests that the particular uses of solar power in rural Sri Lanka is inadequately understood as a cultural preference, but is rather due to the particular properties and material capacities of the SHSs and the manner in which these were assembled. The chapter thus argues that in order to understand how solar comes to make a mark on everyday life and beyond in different places, more curiosity towards exactly what it powers, when, for how long and as a replacement for what kind of other resource is needed.

7.3 Noticing diffractions and re-assembling solar:

The analysis of the two different solar assemblages in Sri Lanka and the UK shows how these assemblages have a force of their own and how the particular agency of individual parts of the assemblage come to crystallize or is achieved within these assemblages. Bringing these assemblages together, or more precisely, paying attention to the diffractions and interferences between them, provides an opportunity to re-assemble solar power and question it not as resource, commodity or instrumentality, but as an actant (Bennett 2005). The following three sections re-assemble solar power in relation to its material agency (7.3.1), temporality (7.3.2) and indeterminacy and social value (7.3.3)

7.3.1 Portions of power: the conspicuous agency of electricity in different assemblages

Despite the very obvious quantitative differences between available power in households in Sri Lanka and in the UK, in both assemblages solar acts as a portion of power. This results in different approaches to use the available electricity up. The manner in which this becomes a meaningful thing to do relates to the respective assemblages. In the UK using as much of the power as possible comes with a small financial bonus and is exaggerated by a technical arrangement in which electricity inside the household is made very visible by a number of monitoring devices whilst electricity leaving the household is difficult to see. From its place within this particular assemblage solar electricity becomes a particular kind of electricity – one which it makes sense to use up, one which has less power and value outside the house. In Sri Lanka, the small amount of available power along with a finite storage capacity in the battery makes it meaningful to budget the power so that it is used up by the time conditions are right for new generation. In both cases the logic of using up turns electricity use on its head compared to how it is often made sense of: as an invisible background resource which people do not set out to use as such, but use inconspicuously in everyday practices (Shove 2003). Portions of solar power are differently conspicuous and people put great effort into using up the power by deliberately engaging in electricity-consuming activities which foreground the use of power. What these assemblages then show is how the manner in which electricity is assembled affects its capacity to do work and shapes its properties and propensities. This is an important finding because it suggests that improvements to the effectiveness of solar electricity, its energy efficiency and technical capacity can me made "in the wild" (Callon, Burchell et al. 2011) after diffusion has taken place. Whilst diffusion of devices such as solar panels is often seen as the last (and final) step in their development, this could be re-framed in a manner where empirical knowledge of the workings of devices within everyday assemblages might enable adjustments to be made to their workings or to the arrangement of other agencies within the 'live' assemblages.

7.3.2 Living with clouds and time

Both in the UK and in Sri Lanka, the significance of temporality in both generation and consumption of electricity is very clear. People living with solar were found to have difficulty using the electricity their systems generated "hot" at the time of day when it was being generated as the temporality of daily life provides a less than optimal match to the patterns of available power from the solar panels. Whilst the impact of clouds on solar generation is both expected and taken into account in the calculation of anticipated generation throughout the year, the issue proved to have greater effect on the assemblages of solar than perhaps anticipated. Although the daily and seasonal impact of cloud cover does not prevent solar photovoltaic electricity from providing a satisfactory amount of power as an average over the course of a year, electricity is not used as an average, but as particular power, which is needed and appropriate at particular times. So what became clear in the two different assemblages of solar is that the capacity, appropriateness and "resource-ness" (Li 2014) of power has a lot to do with its temporality.

The use of solar electricity, as opposed to grid electricity, requires qualculation (Cochoy 2008); consideration, budgeting and monitoring. The intermittency of solar power is generative and makes it appropriate for powering only a certain type of events; events which can be shifted in time, powered otherwise (by taking the battery to be charged at the shop or by using grid-electricity) or potentially not done at all (like watching TV during the rainy season or drying clothes in a tumble dryer in the summer). Recent contributions to the social study of energy has suggested that the temporality of energy use must be better understood (Walker 2014), and this thesis suggest that with particular powers such as solar and other renewable and intermittent sources, the material agency of flows of electricity too is important to understand. The temporality of solar generation in this thesis had different impact in the two solar assemblages. It played an important part in assembling some solar electricity as free and green and other solar electricity as waste, as the following section elaborates on. In Sri Lanka the perhaps most pertinent issue of temporality was the impact of solar electricity assembled as a temporary power and the self-fulfilling consequences this assemblage had on the longevity of the systems and the people using them.

7.3.3 Indeterminacy and the relative social value of solar power

Devices in assemblages are indeterminate (Braun and Whatmore 2010). Solar panels in everyday assemblages were found to be ambiguous actors both in Sri Lanka and the UK. Chapters 5 and 6 both show how unintended consequences occur in the everyday uses of solar (like the use of tumble driers in the summer or the increased use and discarding of car batteries) and how the impact of this on the different kinds of calculated expectations of return on investment and environmental impact are difficult to make.

Solar electricity across the two assemblages was not a single, linear resource which was independent of its socio-material enactments. Just like money or any other kind of resource, solar electricity, or any other kind of electricity, has social meaning (Zelizer 1997, Li 2014). But importantly, people allocate electricity to different tasks not simply because of cultural and social patterns or interpretations external to the material capacity of flows of electricity, but in response to its agency in everyday life. The in-separability of meaning and matter and the process through which they act together has been an important analytical factor in this thesis. The effectiveness of power is therefore a differently complex issue in a domestic household, than it is in conventional physics and engineering; the manner in which people allocate or invent tasks for the new power to do, shows clearly how the social value and qualitative power of electricity is different at different times of day. This brings out a qualitative property of electricity: it derives some of its social usefulness from being available in certain quantities at certain times of day. Whilst this characteristic of electricity can be easily overlooked in the UK where electricity has been shaped as a 'timeless' resource by the electricity grid, solar assemblages in both locations brought it out very clearly. In Sri Lanka as well as in the UK electricity which is available at midday and in the summer, does not have the same kind of social value as electric power (imagined or readily available) which is available in the evening and in the winter. This kind of qualitative value of solar electricity is important to understand. It lies at the heart of the difference between 'solar' and 'electricity' in Sri Lanka. It plays an important part in why poor people in rural villages in Sri Lanka save up and buy appliances they know they cannot yet power in anticipation of grid electricity, whilst enacting the solar electricity they do have as a different, temporary affordance. It also has significant explanatory power in understanding the notion of surplus electricity in the UK: electricity, which is considered a waste because it is available at a time when it is not needed and because it is arranged in a particular way. That electricity is also qualitative, that it can come to be considered more or less useful and (socially) powerful in different arrangements, has important consequences for how transitions to lower carbon living or more sustainable living is imagined. It means that the green-ness, or the sustainability of a particular resource such as solar photovoltaics cannot be considered a neutral attribute of the technology, but becomes rather something to be achieved by a particular assemblage.

7.4 Contributions

The findings in this thesis contribute to the respective knowledges of the use of solar photovoltaics in the respective locations in Sri Lanka and the UK. Drawing these findings together, the thesis contributes in particular to fields of energy research and human geography more broadly with the two aspects demonstrated in the following section: the conceptualisation of electricity as agency and the ethnographically informed enquiry of assemblages.

7.4.1 Electricity as agency

The main contribution of this thesis is to the study of different uses and material politics of domestic energy. It offers a way of conceptualising electricity or energy more widely as agency, in order to move the enquiry of energy away from a conceptualisation of energy as a background affordance, something to be consumed, particularly within households, and towards an understanding of its material force as an actant that shapes modes of social ordering.

The thesis offers a means of questioning the powers of solar electricity as a lively force and take seriously the vitality of flows of solar electricity as electricity, questioning their capacity "not only to impede or block the will and designs of humans but also to act as quasi agents or forces with trajectories, propensities and tendencies of their own" (Bennett 2010: viii). By considering solar electricity as an actant rather than a neutral resource, this thesis contributes to efforts to conceptualise power, not only as capacity to power certain devices and services, but also power to affect modes of ordering beyond these. We have good accounts of how fossil fuels and modern society and democracy have emerged in intra-action (Hughes 1983, Nye 1998, Mitchell 2011) and this thesis contributes to this project of understanding what particular powers with their own 'trajectories, propensities and tendencies' can do and what they can (or cannot) make human beings and domestic settings do, specifically in the context of transitions to renewable energy sources.

As global reliance on fossil fuels is threatened and transitions towards greater reliance on other forms of power are underway, renewable energy technologies such as solar photovoltaics play a crucial role in a very important engineering project: that of manufacturing particular new worlds whilst preventing others. This creates a need for social enquiry to understand what kind of vibrant powers these new forms of energy have, how they differ from other fuels, and how their particular enrolment in all manner of local and global situations open up or narrow down possibilities whilst co-shaping new ontologies and realities. Appreciating not just that renewable energies are different, but that certain specific differences matter more than others is an important step towards being able to achieve not just efficient and green but also socially appropriate and powerful energies. The specific properties and propensities of solar electricity as they came to act within the everyday lives encountered in this thesis were not those of a neutral resource which provided open-ended conditions of possibility for social orderings. It was a particular power and it assembled particular socio-material orderings, which are insufficiently understood as merely interpretations or cultural narratives of (neutral) energy.

By focusing on how solar electricity enabled certain enactments and prevented others this thesis argues against seeing electricity as an immutable mobile which does the same wherever it goes. Instead solar has emerged as a particular kind of force: one which is available at certain times and not others, one which powers certain loads but not others and one which wants to be used up, whether connected to a grid or to a battery. In the context of the UK the thesis has shown how difficulties of compatibility arose when people attempted to re-assemble the capacities of solar into existing everyday habits and patterns, which have emerged and usually operate in assemblages dominated by grid electricity. In the context of Sri Lanka we saw how solar power was very prescriptive and limited in everyday use, and how an intermittent power like that provided a poor material basis for lasting change both for households and for wider rural areas. Whilst the question of which devices and appliances have more power to improve quality of life in out of the way places is a thorny one, the thesis has proposed that efforts to 'provide electricity' are more appropriately thought of as efforts to provide specific services or to power differently. Solar panels we have seen do nothing without particular loads and putting electricity to use in domestic homes is using it for a particular task and in the context of a particular temporal assemblage.

Approaching solar as an actant, this thesis proposes that it has multiple powers in different assemblages and that there is an analytical need to separate in particular the abilities of solar panels to behave as successful commodities with power to 'get out there' to households in both the UK and in Sri Lanka and the power of solar electricity to power everyday life in domestic settings appropriately, and not take the success of one power as evidence of success of another. Being a scalable power is not necessarily the same as being the appropriate power for different social tasks.

This thesis thus proposes an alternative reading of domestic energy use which avoids seeing human beings and the social and cultural worlds they are engaged in as agencies whilst rendering energies passive or inert. People intra-act with flows of energy which are both meaning and matter. Being curious not only about how human beings 'behave', but also how particular energies 'behave', forces a reconsideration of what it is that happens when energy is at work in domestic households, particularly how this relates to what happens elsewhere in much wider energy systems, whether already existing or emerging.

7.4.2 The Power of Ethnographic Assemblages

This thesis makes a case for the critical potential of assemblage thinking within human geography. The analysis in this thesis provides an example of how the concept of assemblage can be put to work in enquiries of how process and formation of various geographies come into being and also how specific socio-spatial formations could be otherwise (McFarlane and Anderson 2011).

Working ethnographically with notions of assemblage as this thesis has done provides a methodological means of unpacking socio-material entities whose shape and size are not easily determined, through investigating them as processes and formations on the move. Focusing on how solar assemblages form and re-form in time through the processes of everyday life, this thesis argues that an emphasis on how devices in assemblages are lived with over time, holds potential for future enquiries of what it means for technological innovations to work in both space and time.

Working through the achievement of two very different assemblages in two very different places this thesis further emphasizes the adaptability and fluidity of assemblages as analytical tools. The question of what is or is not part of a given assemblage is the task of analysis and is thus contestable. This thesis argues that this is what gives assemblage thinking its critical potential: the capacity not just to describe, but to re-assemble, and critically: to re-assemble from some-where. An ethnographically based assemblage cannot provide a view from no-where, rather it can contest and challenge it. Walker and Day have recently highlighted the capacity of assemblage analysis to reveal internal inconsistencies and idiosyncrasies in the context of energy vulnerability (2013), and this thesis has provides an example of this potential by making visible some of the unintended consequences and ambiguities at play in particular solar assemblages. Reassembling solar from the point of view of everyday life provides an account of how such unintended consequences and ambiguities come into being through the coming together of distributed agencies which would not have been visible through a more linear cause-and-effect analysis focusing purely on the agency of consumers or the material capacity of solar panels or batteries.

Focusing on processes of assemblage rather than set places or geographical locations in this thesis contributes to debates about how geography matters in energy studies by providing a means of enquiring not about how two geographically different places are different but how geographies of solar electricity are assembled differently. Assemblages in this thesis are a tool for analysing difference as achievement: questioning how (and where) difference is made, un-made and re-made. It contributes here to on going efforts within geography to find ways of considering how both spatial and temporal variations come into being, and particularly how these can be understood across geographical locations which are not straightforwardly comparable entities (McFarlane and Robinson 2012). Solar assemblages do not promise to be coherent or straightforwardly comparable objects, but are arrangements of 'more than one but less than many' (Law 2002) which do not necessarily 'add up' to one single object with one single kind of agency. In the analysis of solar assemblages this has led to a questioning of what it means for solar panels to work in a particular place at a particular time and how the success criteria and different kinds of impact evaluations at work in different places may leave something out (Winther 2015). This opens up on the one hand a less linear understanding of what might be possible and on the other hand enables a different kind of consideration of how things may be re- assembled otherwise, empirically as well as analytically.

7.5 Policy implications

This thesis argues that an emphasis on diffusion is inadequate in the case of solar photovoltaic technology, both in the context of energy and climate change policy and in the context of international development and electrification. It argues that device-centered predictions and evaluations of the impact of solar panels are insufficient and that the impact of the everyday assemblages they operate in are insufficiently anticipated and evaluated. It suggests that a better understanding of the socio-material impact of different enactments of intermittent Renewable Energy Technologies such as solar photovoltaics in everyday life can improve both their social and material capacities.

A better understanding of how and what situated solar assemblages power in everyday life, provides an alternative route for analysing unintended consequences and for considering the real-life impact of solar diffusion, both the impact on the lives of people and communities using the technology and the environmental impact of particular uses. Having shown how Solar Home Systems in Sri Lanka were both a very specific and a temporary power, raises questions as to whether the technology is able to provide a lasting and sustainable energy transition and in turn questions of how its impact both socially and environmentally is being and could be predicted and measured. It argues that more emphasis on everyday assemblages is needed in order to establish what makes a particular power an appropriate power. It further argues that as energy assemblages have been found to change over time, the continued longer term impact of devices such as Solar Home Systems need to be further investigated. As global concerns over energy access and development come to converge in particular geographical locations, there is a need to consider the particular properties and temporalities of different resources and 'portions of power'.

The ethnographic findings around the RERED project in Sri Lanka has shown how this project could be considered both a success and a failure using different success-criteria and different timescales. They indicate that if a technology such as SHS is not understood to provide a lasting change to people's lives, it is not enacted as such. The often rehearsed notion of customers overusing batteries because of a lack of education is thus insufficient; if a power is understood to be temporary it is unsurprising that it is enacted as such.

The manner in which domestic FIT supported solar installations are assembled in the UK further suggests that a number of ambiguous consequences have come as a result of the manner in which the technology is enacted in daily life, with issues such as people being encouraged to use up power in ambiguous and potentially unsustainable ways and in the potential translation of un-metered export into waste. Whilst this research is based on a small qualitative sample of people, it indicates that the use of devices in transitions to greener and more sustainable forms of energy consumption are vulnerable when they are not based on an understanding of the kinds of everyday assemblages solar photovoltaic technology operate within. In particular the thesis has argues that the potentially unsustainable results of everyday enactments of solar remain unclear as long as they are understood in cause-effect terms to be the 'fault' of single actors, be those human beings, export meters or Feed-in Tariffs, and that the force of specific assemblages needs to be better mapped and incorporated into planning.

7.6 Future Research

A number of potentially interesting questions have emerged through the process of this PhD but have fallen outside of the initial scope of this thesis and have therefore not been developed in the thesis. The following section outlines two areas of future research which this thesis has touched on very briefly, but which have yet to be developed further. These are firstly questions around energy temporalities and particularly notions of habit and secondly questions of energy democracy and energy publics.

Notions of temporality and seasonality were very important in both ethnographies in this thesis, and have not been developed as much as it would have been interesting to do. Recent work within Human Geography has begun calling for greater attention to temporality in relation to energy use (Southerton 2013, Walker 2014) and this thesis has already suggested that temporality and seasonality played important roles in everyday enactments of energy uses. Elsewhere in social and philosophical enquiry there is a renewed interest in the work of the philosopher Henri Bergson and his capacity for "thinking in time" (Guerlac 2006, Grosz 2013), an influence which is also very present in Tim Ingold's recent work (Ingold 2011) which has helped this thesis make sense of the manner in which people live with weather as opposed to climate, a challenge which this thesis suggests holds a great deal of promise in understanding how relations between *the home* and *the environment* may be understood. The fieldwork carried out for this thesis suggests that noticing and understanding how energy use happens in time and in relation to differences in seasons, can not only contribute to our understanding of patterns of energy demand (Walker 2014) but also to questions of how specific uses of energy at particular times become part of the ongoing emergence of people being with weather and climate (Ingold 2000, Ingold 2011). A particularly interesting line of thinking in relation to energy use is recent efforts to re-conceptualise of the concept of habits as fundamentally creative (Ingold 2011, Grosz 2013). Whilst notions of habit have often reduced the human to the order of the mechanical following the conceptual lineage of Decartes, Kant and Sartre, Elizabeth Grosz has suggested that a re-thinking of habit which sees it instead as a mode of encountering environments and materiality following the work of Ravaisson, Bergson and Deleuze, has much to offer (Grosz 2013). Grosz outlines how habits both in policy and social research have been regarded as something to be managed and regulated, privileging 'good habits' whilst punishing 'bad' ones, and that this rests on an understanding "that habits are the part of us that can be adjusted, altered, oriented in one way or another, that they are the part of us that can be manipulated, perhaps even from the outside, to attain various goals" (Grosz 2013: 234). Lunch-time clouds, as enacted in Chapter 5 in this thesis, get in the way of this understanding by showing not only that uses of power have timings that matter, but also that they are assembled within particular environments of distributed agencies, suggesting that habits may not be as straightforwardly thought of as 'low hanging fruit'. Grosz articulates, I think, something of a challenge for future research on energy uses, which incorporates notions of temporality and habit: "It may thus be able to discern another dimension to habits than those that make habit the object of social manipulation. Habit is one of the modes of connection that link living beings to a world, which is open to innovative behaviour.... It deserves to have its ontological place restored" (Grosz 2013: 234). Solar photovoltaic technology, due to its necessary relationships between power, temporality and weather provide a rich site for exploring this further.

The insights from this thesis could further be usefully put to work in relation to ongoing work concerned with the concept of energy publics, which is receiving increasing attention both in the governance of science and technology (Lezaun and Soneryd 2007) and in energy research and policy, where the understanding of what people think and do is becoming increasingly framed as critical to successful 'energy transitions'. Investigating the explanatory power of such a concept is therefore timely. As the idea of a future energy public is becoming more popular however, recent academic attention on the issue of energy publics has pointed out, that dominant approaches tend to articulate a simplistic view of publics, imagining them as an 'external public existing in a natural state waiting to be revealed, engaged, or mobilised by science and democracy' (Chilvers and Pallett 2014). In response to this they call for further development of the concept of energy publics understood as *emergent* and co-produced.

Drawing not least on the broader field of STS scholarship with its insights on the co-production of social, political and technical orders (Jasanoff 2004), this interest in energy publics lies not just in the question of who they are and what they think and do (as is the immediate interest for policy purposes) but *how they happen* in particular ways in particular *material,* political, technological, and social settings. This then fleshes out an understanding of publics which is not one of relatively stable groups of human beings with particular interests and ideologies as envisaged in Habermasian models of deliberative democracies, but rather as hybrid assemblages which are better understood in line with ideas about what Latour has called a 'parliament of things' (Latour 2005) which invites an enquiry into "how relations between science, governance and society would need to be reconfigured in order to better account for the inherent uncertainties, diversities, materialities, and competing visions of emergent energy publics" (Chilvers and Pallett 2014). This is an important step for a future oriented social enquiry of energy and power: reconfiguring relations in a heterogeneous assemblage of human and non-human forces and entities, is a different job than reconfiguring intentional human beings.

A number of competing theoretical underpinnings for the idea of an energy public are then emerging (see Chilvers and Pallett 2014 for a review), and addressing similar issues to those touched on in this thesis, with Noortje Marres' work on material participation (Marres 2012) being a central node. Marres and Lezaun have further outlined a mode of enquiry which questions the manner in which objects, devices and settings acquire political capabilities (Marres and Lezaun 2011), as already discussed in this thesis. This foregrounds the capacity of technologies or devices, to bring a public into being. A device centered approach provides a means of investigating an emergent public as assembled by a device such as a solar panel or indeed a particular vibrant materiality such as solar electricity. Considering the notion of energy public as assembled by particular devices, or considering devices as potential co-producers *of* new social, political and moral relations which assist or hinder 'entanglement' with particular issues or matters of concern, provides an interesting next step for the findings in and the analytical approach of this thesis (Callon and Rabeharisoa 2004).

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