The role of the small-scale feed-in tariff in electricity system transition in the UK

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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Abstract

Carbon reduction commitments and renewable energy targets have become legal drivers of electricity policy in the UK. Meeting those targets will require a transition in the way that electricity is generated, supplied and consumed. This thesis argues that small-scale renewable electricity technologies (<5MW) could have an important role in driving that transition. The thesis evaluates the role of the feed-in tariff - a policy mechanism designed to stimulate the deployment of small-scale renewable electricity technologies - in electricity system transition in the UK.

The research is based on empirical information generated from 37 industry interviews, observations of industry and government meetings and events, and secondary analysis of consultation responses, publications and statistics from government and the energy regulator, Ofgem. The analysis is structured with a framework that draws on transition theory and breaks down the findings into a niche (micro/developing) level, a regime (incumbent electricity system) level and a landscape (contextual) level.

The thesis finds that the FIT has driven solar photovoltaic development and innovation at an unprecedented rate. The other renewable technologies supported under the FIT (wind, hydropower and anaerobic digestion) have not been as widely deployed. It is argued that additional policy support is required to overcome the non-financial barriers that these technologies face. The thesis concludes that the role of the FIT in system transition has been to drive a level and pace of activity in the solar sector that has demonstrated the potential for alternative generation options. This has informed the politicised debate around electricity policy in the UK but it is argued that continued, broader, stable support is required if small-scale renewable technologies are to have a positive role in electricity system transition.

The research has relevance to both academic and policy circles focused on electricity policy, the decarbonisation of energy systems and socio-technical system transitions.

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Acronyms

Acronym	Term

BERR	Department of Business, Enterprise and Regulatory Reform
BIEE	British Institute of Energy Economics
BCSE	Business Council for Sustainable Energy
CCC	Committee on Climate Change
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage/Sequestration
CEGB	Central Electricity Generating Board
CERT	Carbon Emission Reduction Target
CHP	Combined heat and power
DC	Direct Current
DEFRA	Department of Environment, Food and Rural Affairs
DNC	Declared Net Capacity
DNO	Distribution Network Operator
DTI	Department of Trade and Investment
EA	Environment Agency
EIS	Enterprise Investment Scheme
ETS	Emissions Trading System
EU	European Union
FIT	Feed-in tariff
GB	Great Britain
IEA	International Energy Agency
LA	Local Authority
LCBP	Low Carbon Buildings Programme
LSP	Local Strategic Partnerships
MCS	Microgeneration Certification Scheme
MW	Megawatts
OFFER	Office of Electricity Regulation
OFGEM	Office of the Gas and Electricity Markets
ORED	Office of Renewable Energy Deployment
PRASEG	Parliamentary Renewable And Sustainable Energy Group
PV	Photovoltaic
RDA	Regional Development Agency
REC	Regional Electricity Company

RO	Renewables Obligation
SPV	Special Purpose Vehicle
STS	Science and Technology Studies
UK	United Kingdom
VAT	Value Added Tax
VCT	Venture Capital Trust
WPD	Western Power Distribution

Chapter 1 Introduction and Context

SECTION 1.1 CHAPTER INTRODUCTION

The UK electricity sector is at a crossroads. Carbon reduction commitments and renewable energy targets have become legal drivers of electricity policy. Meeting those targets will require a transition in the way that electricity is generated, supplied and consumed. This transition could develop along any number of pathways with different combinations of technologies, actors and practices and policy will have a role in shaping the direction that is taken. This thesis evaluates the role of the feed-in tariff - a policy mechanism designed to stimulate the deployment of small-scale renewable electricity (RE) technologies - in electricity system transition in the UK.

The small-scale feed-in tariff (FIT) was only introduced in April 2010 and it is therefore still an emergent development in the UK energy policy framework. This research contributes to existing knowledge by identifying the impact the FIT has had so far on the transition of the electricity system and what factors are influencing the efficacy of the policy itself. To structure the analysis the academic theory of system transitions is used.

The research findings are based on empirical information generated from three sources:

1. A set of 37 semi-structured face-to-face interviews with purposively selected participants;
2. Observations of industry and government meetings and events;
3. Secondary analysis of consultation responses, publications and statistics from government and the energy regulator, Ofgem (these are explained in Chapter 4).

The sections in this first chapter are split into three groups –

i. The background energy and policy context – Section 1.2 – 1.5;
ii. The FIT and limitations of conventional policy analysis – Section 1.6 and 1.7;
iii. Research questions and structure of this thesis – Section 1.8 and 1.9.

SECTION 1.2 THE EMERGING DRIVERS OF ENERGY POLICY: CLIMATE CHANGE AND ENERGY SECURITY

Global climate change is now unequivocal with evident '*increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea levels*' (IPCC, 2007, p.30). This change in the earth's natural systems demands urgent action of an unprecedented scale to address the environmental, social and economic impact (Stern, 2006). The principal cause is escalating emissions of greenhouse gases[1] generated from the combustion of fossil fuels. In 2008, this provided 85% of global primary energy and made up 54.4% of anthropogenic greenhouse gas emissions (IPCC, 2012). The escalation of emissions is being driven by an increasing global demand for energy which the International Energy Agency (IEA) predict will continue to increase by 1.5% annually up until 2030 (an overall increase of 40%) (IEA, 2009). In addition, since the early 2000s the carbon intensity of energy supply has increased, mainly due to growth of the combustion of coal (IPCC, 2012).

At the end of 2010 the concentration of greenhouse gases in the atmosphere was 390 parts per million of carbon dioxide equivalent (ppm), 39% above pre-industrial levels. To limit global average temperature rise to 2°C, the Cancun Agreements of 2010 called for a maximum concentration of 445 – 490ppm. This will require a reduction in global carbon emissions of 50 – 85% below 2000 levels by 2050 (IPCC, 2012). The advised levels of carbon reduction will undoubtedly require significant changes in the world's energy systems.

In addition to concerns over climate change, amongst Western nations in particular, growing anxiety over the security and availability of affordable energy resources is challenging the stability of energy systems. The long-term supply and demand outlook of fossil fuels, increasing volatility in fuel prices, fears over energy-related terrorism, and concerns over the physical availability of resources is increasing the pressure for energy systems to diversify and find alternative means of generation and supply (Helm, 2003; Kuzemko, 2009; Winzer, 2012). The response to concerns over climate change and energy

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[1] The basket of greenhouse gas emissions includes carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. Carbon dioxide is the greatest contributor to climate change (IPCC, 2007).

security differs by country but the focus of this research is the United Kingdom (UK). Although the UK has a unique energy system-history it also shares many characteristics with other developed nations and this thesis therefore provides an illustrative account that is relevant beyond the UK.

SECTION 1.3 THE CLIMATE CHANGE AND ENERGY POLICY CONTEXT IN THE UK

In the UK the central policy response to climate change has been the legally binding commitment made in the 2008 Climate Change Act to reduce UK carbon emissions by 2050, by 80% from 1990 levels with an interim target of 34% by 2020 (HMG, 2009a). Energy production and consumption, which accounts for approximately 95 per cent of all UK carbon emissions, is spread across three energy sectors; electricity, heat and transport (DECC, 2011b). The decarbonisation of the energy system is therefore integral to the UK's response to climate change (CCC, 2008).

Although the electricity sector is the smallest of the three energy sectors accounting for 23% of total energy consumption, the UK Government have indicated that it is the priority sector for decarbonisation (HMG, 2011). There are two main reasons for this -

1. A large proportion of the transport and heat sectors are predicted to electrify before 2050 (DfT, 2010; DECC, 2011h). If this electrification is going to significantly reduce emissions across the whole economy then the electricity being used for heat and transport must be derived from low-carbon sources. Thus the electricity sector must be decarbonised as a priority so that the electrified heat and transport technologies will be using low or zero-carbon power.
2. The existing electricity system is highly centralised, and based around a small number of very large emitters (see below, this section). There are therefore fewer units to decarbonise than in the heat and transport sectors where the emissions are generated by very large numbers of dispersed units. The electricity sector is therefore currently seen to be easier to decarbonise (DECC, 2011h; CCC, 2008; HMG, 2011).

The Committee on Climate Change (CCC), who advise government on how to meet their decarbonisation targets (see Chapter 2 Section 2.4.2), have recommended that the electricity sector must completely decarbonise by 2030 if the wider economy is to reduce its emissions by the required 80% by 2050 (CCC, 2008). The electricity sector is therefore predicted to play an increasingly critical role in the UK's response to climate change and the way in which it is structured, directed and regulated will have wide-ranging implications. For these reasons this study focuses on the electricity system in the UK.

The existing electricity system in the UK is a highly centralised network of mostly large thermal and nuclear generating stations (Ofgem, 2008; Pepermans et al, 2005; Abu-Sharkh et al, 2006). Decarbonising the system is challenging because the existing physical infrastructure has a stability that is reinforced by institutions and practices that have evolved alongside it (see Chapter 2) (Mitchell, 2008; Shackley and Green, 2007; Scrase and MacKerron, 2009). However, the UK Government has stated that '*by 2030 we will have a flexible, smart and responsive electricity system, powered by a diverse and secure range of low-carbon sources of electricity'* (DECC, 2011b). The transition that is required to deliver that system could involve different balances of technologies, institutions, and actor-roles (Foxon et al. 2010). This thesis will argue that the balance should include significant levels of small-scale RE technologies (see Section 1.5) but at present the UK Government's long-term approach for generation centres primarily on large-scale technologies such as Combined Cycle Gas Turbines (CCGTs), carbon capture and storage (CCS) from coal and gas plant, nuclear power and large-scale wind (DECC, 2011a & 2011b).

The RE element of UK electricity policy is driven by a legally binding commitment that was created by the European Union's (EU) 20:20:20 targets signed in 2007. Signatories are collectively required to achieve the following by 2020 -

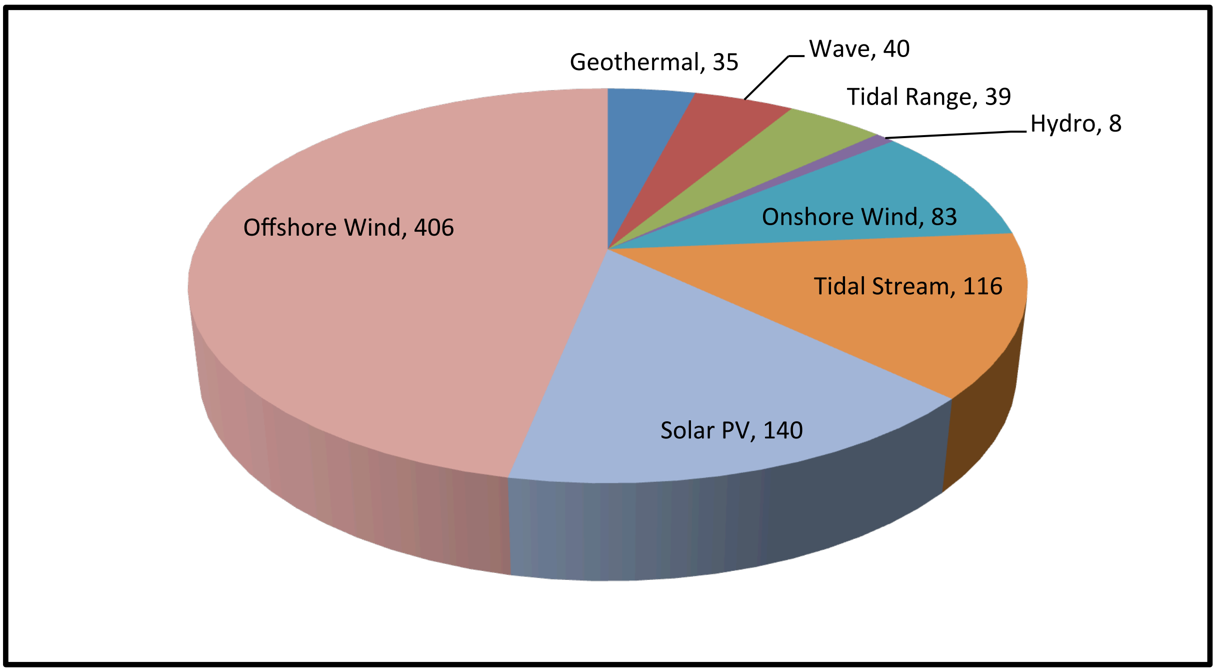
1. A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels;
2. 20% of EU energy consumption to come from renewable resources;
3. A 20% reduction in primary energy use compared with projected levels, achieved by improving energy efficiency (European Commission, 2010).

Each signatory country has individual targets that were negotiated when the commitment was signed. The UK's share of the RE target is 15% of total energy by 2020 (HMG, 2009a). The UK Government has indicated that if the overall target is to be met, around 30% of electricity will have to come from renewable sources due to the challenges associated with renewable transport and heat technologies, as discussed above. But in 2011 just 9.4% of electricity was generated from renewable sources and 3.8% of total energy despite the UK having the largest potential wind energy resource in Europe and substantial potential in marine and solar technologies (HMG, 2009; DECC, 2012) A step-change in delivery is therefore required if the 2020 target is to be met.

SECTION 1.4 THE POTENTIAL RENEWABLE ELECTRICITY RESOURCE IN THE UK

Figure 1.1 below illustrates the practical resource in the UK for a number of RE technologies at all scales. The **Practical Resource** is an estimation of the upper level of deployment that would be acceptable to society given the natural and technical resources available and taking account of ecologically sensitive areas, existing manmade structures and usages such as shipping lanes (CCC, 2011a).

FIGURE 1.1 ESTIMATED PRACTICAL RESOURCE FOR UK RENEWABLE ELECTRICITY (TWH/YEAR)



Source: CCC 2011b

The total practical resource for the eight technologies selected above could generate 867 TWh/year. The higher projections for electricity demand in 2050 in the UK are just over 500 TWh/year so the potential renewable resource is very significant (CCC, 2011a). The economic potential is more difficult to predict because investment in RE is dependant on wider political and economic trends but Arup have produced a range of economic projections that suggest that between 105 and 195TWh/year could be generated from RE by 2020 and between 220 and 425TWh/year by 2030 (Arup, 2011). Thus there is a very significant RE resource base in the UK and it is estimated that there is the economic potential to exploit a significant proportion of it.

Maximising the potential resource will require a diverse range of technologies, of varying sizes, deployed in differing locations. This will require direct policy support to create a portfolio of options as the quote below from the Stern Review indicates –

'The power of market forces is the key driver of innovation and technical change but this role should be supplemented with direct public support for research and development

and, in some sectors, policies designed to create new markets. Such policies are required to deliver an effective portfolio of low-carbon technologies in the future' (Stern, 2006, p.373).

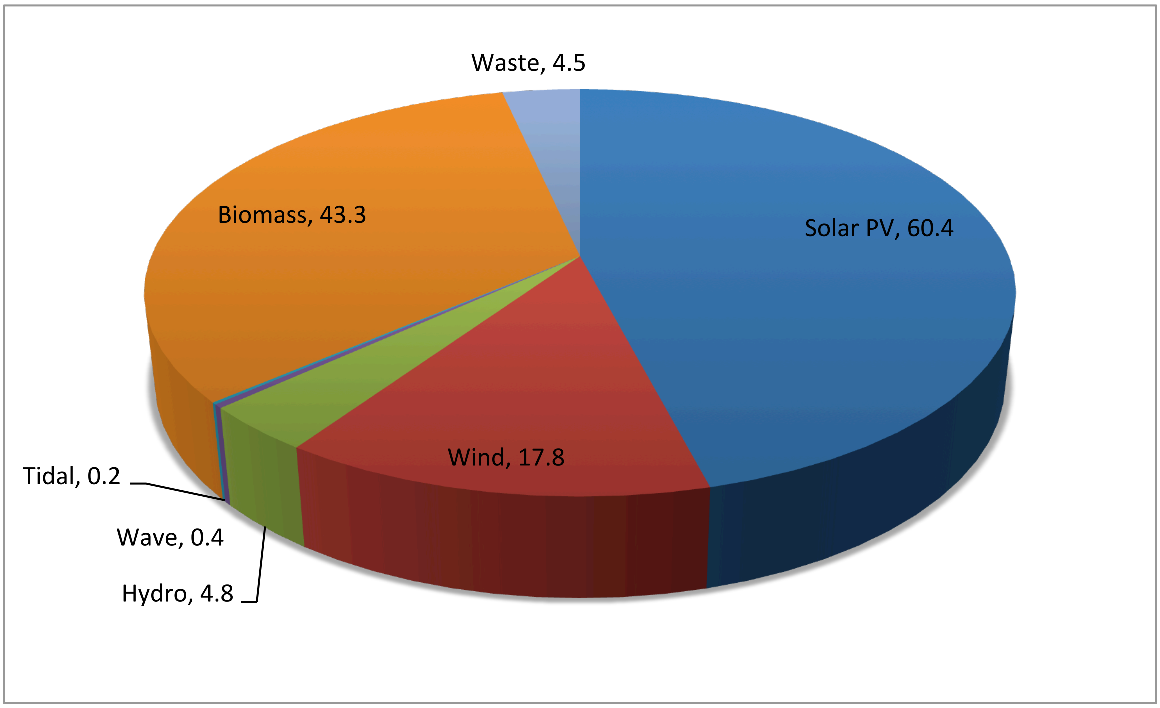
However, since its introduction in 2002 the Renewables Obligation (RO), which is the primary support mechanism for RE in the UK, has delivered mostly large-scale, mature technologies, owned by a small number of established commercial actors (DECC, 2012c; DECC, 2010a; Ofgem, 2008a; Mitchell, Woodman and Aldridge, 2010; Hain et al. 2005). It has not mobilised large amounts of smaller scale RE development, or large numbers of new market entrants, because the costs, complexities and risks of participating in the scheme are too great for small-scale technologies (this is discussed in detail in Chapter 5 Section 5.3) (Toke, 2007; Mitchell et al. 2006). As the Department of Energy and Climate Change (DECC) state, the RO *'can be difficult to understand and navigate for those not familiar with the electricity market, and at the very small scales the returns offered* (are) *not sufficient to justify investment* (DECC, 2010a, p. 1). This thesis does not evaluate which portfolio of technologies would be optimal for achieving the UK's carbon and RE targets; rather the focus is on the contribution that small-scale RE technologies are making, and the impact that the FIT has had in supporting them.

SECTION 1.5 THE POTENTIAL OF SMALL-SCALE RENEWABLE ELECTRICITY IN THE UK

Small-scale RE is defined here as RE technologies under 5MW. The technologies included within the definition are wind, hydropower, solar photovoltaics (PV), wave, tidal stream, tidal barrage, waste, anaerobic digestion, and other bioenergy. This thesis focuses mainly on wind, hydro, solar PV and anaerobic digestion (AD) because these are the renewable technologies supported by the FIT (see Section 1.6 below). Where the terminology 'small-scale RE' is used in this thesis it is making a deliberate distinction between RE technologies under 5MW and 'RE' which is used to refer to renewable technologies at all scales.

The **technical potential** for small-scale RE (sub 5MW) is 131.2TWh/year (Element Energy and Poyry Consulting, 2009). The technical potential signifies the maximum electricity that could be generated per year, in the UK, for a given technology. It is based on the available resource and the limitations of the technology (Element Energy and Poyry Consulting (2009)[2]. Figure 1.2 shows the breakdown by technology of the technical potential of sub 5MW RE.

FIGURE 1.2 TECHNICAL POTENTIAL OF SMALL-SCALE RENEWABLE ELECTRICITY (TWH/YEAR)



Source: Element Energy and Poyry Consulting, 2009

It is not possible to accurately compare this technical potential with the practical potential of all RE calculated by the CCC, or the economic potential calculated by Arup outlined in Section 1.4 above, because they contain differing constraints. However, the higher projections for electricity demand in 2050 are just over 500 TWh/year so the technical potential of small-scale RE at 131.2 TWh/year is still significant even if not fully exploited (CCC, 2011a).

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[2] It is important to note that this potential is a different calculation to the practical resource of RE at all scales that is outlined in Figure 1.1 above. Calculating the potential of a renewable resource involves a number of estimations on how deployment could develop and these differ between calculations. But the different potentials outlined in this chapter are included not for comparison but to show that the renewable resource is significant, including at the smaller scales.

Small-scale RE technologies also have a number of characteristics that could benefit the drive towards a decarbonised and sustainable electricity system. They potentially access a wider variety of energy sources, locations, points of connection to the network, supply chain requirements, and ownership structures that could *increase* resilience to potential shocks by spreading the risk across a more diverse electricity system (Ofgem/BERR, 2008; Mendonca, 2007; DECG, 2012). However, there are also a number of disbenefits to small-scale RE development that are discussed in detail, alongside the benefits, in Chapter 2 Section X. This thesis argues that the potential benefits to the process of electricity system transition justify direct policy support for small-scale RE and the research focuses on the FIT which is the mechanism providing support across Great Britain[3] (GB) (see Section 1.6).

Despite the benefits, small-scale RE faces many barriers and constraints to deployment. This thesis argues that because the electricity system in the UK has developed around large-scale, centralised generating plant, it effectively incentivises incumbent technologies, and technologies that display incumbent characteristics (i.e. large-scale and centralised; see Chapter 2). Arthur (1994) argued that the more widely adopted a technology, the more attractive and valuable it becomes; termed 'increasing returns to adoption'. This can ultimately result in a technology becoming dominant in a system and creating a 'lock-in' that prevents the take-up of potentially superior alternatives (Arthur, 1994; Unruh, 2000 and Unruh, 2002). As Chapter 2 will discuss, in the electricity system the dominance of large-scale technologies, and the utilities that own them, has created a lock-in that creates technical and economic constraints to alternative approaches such as small-scale RE. For this reason small-scale RE requires specific policy support (DECC, 2009; DECC, 2010a; Ofgem/BERR, 2008). The following section introduces the FIT.

SECTION 1.6 THE FEED-IN TARIFF

The FIT was introduced in April 2010 across GB. It provides a guaranteed buyer and price for electricity generated and exported from solar PV, wind, hydro, and AD installations up to 5

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[3] The FIT only covers GB (England, Scotland and Wales) but the thesis relates to the UK (including Northern Ireland). The reason for this is that the majority of Government statistics and most academic studies cover the whole UK.

megawatts (MW). It also includes a pilot scheme for 30,000 gas-powered micro-CHP units. These have a distinct set of characteristics and requirements[4] to the other technologies and because this research is focused on *renewable* technologies, micro-CHP is not included in the analysis. The design of the GB FIT is discussed in detail in Chapter 5 Section 5.7.

For the renewable technologies the GB FIT supports, the scheme has been a significant development. In its first two years and five months (as at 31 August 2012) the FIT brought forward a total of 311,479 new installations. However, 99% of the installations have been solar PV, and 94% of those installations were sub 4kW domestic installations. DECC originally predicted that 121,338 renewable installations would be supported by the end of 2012 and so the scheme has far exceeded expectations[5]. But the FIT has also been a controversial mechanism. There are opposing views over almost every aspect of the scheme, as will be discussed in this thesis. To analyse the impacts the FIT has had on the electricity system it is therefore necessary to focus on the experiences and views of different stakeholders in the scheme, as well as the number of installations and deployment trends.

SECTION 1.7 CONVENTIONAL POLICY ANALYSIS AND THE ANALYTICAL FRAMEWORK APPLIED IN THIS THESIS

Evaluations of energy policy tend to focus on the economic or carbon-saving outputs that an intervention creates. The UK Government's policy evaluation is guided by "The Green Book", which is published by the Treasury and provides '*a framework for the appraisal and evaluation of all policies, programmes and projects*' (HM Treasury, 2003; p.1). It focuses on attributing a monetary value where possible, and assessing the costs and benefits of a policy in quantitative terms. Outside of Government, cost-effectiveness analysis and cost-benefit analysis, which are both quantitative evaluation tools, are widely used approaches for evaluating the impacts of a policy, but within the context of sustainability, and complex

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[4] Micro-CHP units differ from the other FIT-technologies in that they generate both heat and power, and the technologies supported under the FIT are also fuelled by non-renewable natural gas. As such they have specific requirements that are outside the focus of this research.

[5] These figures were shown to the author in an interview with a DECC official.

systems, these approaches risk undervaluing important qualitative processes of innovation (Smith et al. 2010; Kern, 2012).

A complex transition is required to move the current system towards a sustainable electricity system which will involve social, technical, economic and institutional factors. Evaluating the role of a policy within this context requires a more inclusive analysis that acknowledges the effects that it is having within wider processes of innovation and change. This research achieves this by moving beyond conventional policy analysis and developing an analytical framework that draws on the academic theory of how innovation and transitions occur within large socio-technical systems such as the electricity system.

Innovation is understood in this thesis to refer in a broad sense to 'the production, diffusion and use of new, and economically useful, knowledge' (Lundvall, 1992, p.17). Edquist (1997) explains that innovation has often been conceived in a narrow sense to refer to technical innovations but innovation in this thesis also describes the development of social, environmental, commercial, and financial knowledge. It is also understood to explain processes occurring at a system level, with multiple interrelating factors. Schumpeter stated simply that innovation '*combines factors in a new way*' (Schumpeter, 1939, p.84) and this is the broad concept applied here.

The analytical framework applied in this thesis has been adapted from Kern (2012) and it is built around a number of processes identified in the academic literature as requirements of transition. Kern used a similar framework to evaluate the impacts of the Carbon Trust, a policy initiative and organisation that is designed to work with businesses and public sector bodies to stimulate a low-carbon economy (see Chapter 3 Section 3.10). He suggests that in order to further his analysis *'detailed empirical analysis of other policy initiatives is required to complement the picture*' (2012, p.308). The empirical information from this research could have been analysed in many different ways, but this thesis builds on Kern's work because his framework provides a coherent structure for using the concepts and indicators of transition, discussed in the academic literature (see Chapter 3). This will illuminate how the policy mechanism is impacting on processes of change, and also how those processes influence the mechanism itself. Thus a contribution of this research is to evaluate the FIT in terms of its role in system transition, rather than focusing solely on its costs or carbon impact. The framework is discussed further in Chapter 3 Section 3.10 and Chapter 4 Section 4.7.

In employing transition theory in this way the thesis responds to a criticism from Smith et al. (2010) that the theory has been inconsistently applied to empirical studies, largely due to the difficulties of '*bounding, partitioning and ordering*' a dynamic, multi-faceted system such as the electricity system (Smith et al. 2010, p.445). It is argued that the framework used here provides a coherent and transparent means of analysing a policy specifically in relation to the *dynamics* of the electricity system. The thesis therefore contributes to the academic literature on transitions by building on Kern's work in applying the theory to current, emergent policy and its impacts on developing transitions.

The FIT is still a relatively recent development for the electricity system in the UK and little academic work has been carried out analysing its impacts. There are two relevant peer-reviewed articles which are briefly reviewed below.

1. Cherrington et al. (2013) – This research presents a financial analysis of two solar PV case studies to determine the impact that changes to the FIT payments has on the economics of typical sub 4kW systems. The return on investment and payback times were calculated for each case study using the three following tariffs -

    - A system installed before 1st April 2012 that qualifies for the tariff level of 43.3p/kWh
    - A system installed after 1st April 2012 that qualifies for the tariff level of 21.0p/kWh
    - A system installed after 1st August 2012 that qualifies for the tariff level of 16.0p/kWh (including an increased export rate of 4.5p/kWh) (Cherrington et al. 2013).

The results of the analysis are shown in Table 1.2 below.

TABLE 1.1 FINANCIAL ANALYSIS OF TWO SOLAR PV INSTALLATIONS UNDER DIFFERENT TARIFFS

	Case study 1 (2403 kWh/year)			Case study 2 (2478 kWh/year)		
FIT rate (p/kWh)	43.3	21	16	43.3	21	16
Return on Investment (%)	9	8	7	10	9	7
Payback time (years)	10	12	12	9	11	12
Net profit (£)	30738	17741	14440	32543	18886	15451

Source: Cherrington et al. (2013)

The analysis assumes a reduction in solar PV panel costs of 30% between April 2010 and April 2012 and continuing at the same rate until the August installation. This has in part compensated for the tariff reduction and so they calculate that a 7% return is still possible under a 16p/kWh tariff. The payback time has increased but only to 12 years. The conclusion is therefore that, despite the changes to the FIT, there is still a healthy return available and deployment will continue.

2. Walker (2012) – this research asks whether the RO and FIT in combination could deliver 2% of electricity supply from sub 5MW installations by 2020. It suggests that 1.6% of supply must be delivered with support of the FIT according to the FITs Impact Assessment and it evaluates whether this might be achieved (DECC, 2010b). The research uses a model called Green-X that was developed by a consortium led by the Technical University of Vienna. The model uses dynamic cost curves and RE policy scenario conditions to determine the equilibrium level of supply and demand for each year for a given country (Walker, 2012).

The modeling developed three outputs depending on the electricity price in 2020. The low electricity price scenario resulted in just 0.37% of electricity supply coming from FIT supported generation. A high electricity price scenario resulted in 1.64% of supply coming from FIT supported generation. The research therefore concluded that *'modeling results show that the FIT scheme could achieve targets set for 2020 provided wholesale electricity prices match the high price scenario'* (Walker, 2012). However, the paper does not actually state what the different electricity prices in each scenario are, it just indicates that a high electricity price is required for the FIT to deliver.

In addition, the model does not allow tariff levels to be differentiated by scale and so a mean price was calculated and inputted for each technology. As the paper acknowledges, this could significantly affect the results of the modeling because the GB FIT has very different tariff levels at different scales and it has seen far more activity within the sub 4kW solar PV tariff band than any other. The model would not reflect this differentiated activity.

The model is also based on technology cost curves and electricity price scenarios that were built with data available when the model was being developed between 2002 – 2004 (Vienna University of Technology, 2007). The user is not able to amend these assumptions and so there is a high likelihood of inaccuracies, particularly in this case in relation to the sharp reduction in solar PV module costs that occurred since the FIT was introduced (see Chapter 6 Section 6.3.1).

The author also acknowledges that the reviews to the scheme require policy evaluation to be constantly updated and she concludes that '*It seems the only thing we can forecast with certainty is further changes to the UK renewable energy policy landscape*' (Walker, 2012).

The paper is a bold attempt to predict the impacts of what has become a very dynamic policy mechanism. Predicting the implications of a new policy is an important contribution but there is a lack of transparency in the assumptions built into the model used in this research which make the conclusions less valid than they could be. It is also based on data that is now outdated.

The two articles make quite different contributions to the one made by this thesis. Cherrington et al. (2013) present a financial analysis of the economics of sub 4kW solar PV and Walker (2012) attempts to predict the contribution to electricity supply that FIT supported technologies will make in 2020. This thesis therefore makes a clear contribution to the literature by focusing on the qualitative, as well as the quantitative aspects of the FIT, and by placing this within the dynamic process of transition in the UK electricity system. The research has relevance to both academic and policy circles focused on electricity policy, the decarbonisation of energy systems and concerned with the FIT.

SECTION 1.8 RESEARCH QUESTIONS

The research questions the thesis addresses derive from the broad context introduced above, and explained in greater depth in Chapters 2, 3 and 5. The central research question is outlined below.

CENTRAL RESEARCH QUESTION

What is the role of the small-scale feed-in tariff in electricity system transition in the UK?

To support investigation into the role of the small-scale FIT the following secondary research questions will be addressed during the thesis.

SECONDARY RESEARCH QUESTIONS

1. What are the trends in deployment for each of the four renewable technologies supported by the FIT?
2. Is the FIT driving a build-up of momentum in the FIT-technology sectors?
3. How is the current electricity system responding to the FIT and what impacts are political, economic and socio-cultural developments having on this response?
4. How could policy be improved to further integrate the FIT technologies into the electricity system?

Each research question is addressed in separate chapters. Question 1 in Chapter 6, question 2 in Chapter 7, question 3 in Chapter 8 and question 4 in Chapter 9.

SECTION 1.9 STRUCTURE OF THE THESIS

To answer the research questions above the thesis is organised in the following way:

Chapter 2 outlines the structure of the existing electricity system in the UK, and it explores the barriers to achieving change and developing small-scale RE. This chapter also provides the background information on the electricity system that places the FIT, and this research within a broader context.

Chapter 3 then explores the theoretical solutions to breaking system lock-in. It explains the process of transition and it introduces the 'multi-level perspective' which is a framework for explaining and analysing socio-technical systems and transition. Within the academic literature a number of processes are proposed as indicators of transition and these are built into the analytical framework. The framework is introduced in this chapter but the way it is applied is explained in Chapter 4.

Chapter 4 outlines the methodology applied to this research. It explains the three empirical strands which constitute the core of the research and then details how these were analysed.

Chapter 5 explains the history and context of RE policy in the UK. It is important to provide this background because the FIT was introduced into a sector that is shaped by the policy support that has been available. In addition, the design of the FIT mechanism was partly a response to the successes and failures of previous policies and it is therefore necessary to understand the design and impact of those policies. The chapter then moves on to outline the reasons why a FIT was introduced, the design of the mechanism and the ways in which it has been reviewed.

Chapter 6 sets out the high-level installation numbers and deployment trends for the FIT and then provides a summary of each renewable technology supported under the scheme. This chapter directly answers secondary research question 1 - What are the trends in deployment for each of the four renewable technologies supported by the FIT? This provides a platform of information that allows for a deeper analysis in the following chapters.

Chapter 7 is the first of two chapters that use the analytical framework to structure in-depth analysis of the FIT. This chapter focuses on the niche level. This is explained fully in Chapters 3 and 4 but it assesses the developments occurring under the FIT for the four renewable technologies and the actors and practices that are directly involved in their deployment. Solar PV, hydro, wind and AD are all defined as their own technology-niche with a unique set of technical factors, dedicated actors, and financing, development, installation and business practices (see Chapter 3 Section 3.10). The chapter answers secondary research question 2 - Is the FIT driving a build-up of momentum in the FIT-technology sectors?

Chapter 8 also applies the analytical framework and explores the processes occurring at the regime and landscape levels. Again, these are explained fully in Chapters 3 and 4 but the regime is the incumbent electricity system including the dominant technologies, actors and practices. The chapter analyses the degree to which the FIT has impacted on these factors and the influence that they are having on the technology-niches. The landscape level describes the broad context that surrounds the electricity system and the chapter evaluates the developments that have occurred at this level and how they have impacted on the progress of the FIT. The chapter answers secondary research question 3 - How is the current electricity system responding to the FIT and what impacts are political, economic and socio-cultural developments having on this response? The chapter then brings the analysis together to assess the ways in which the niche, regime and landscape are interacting. This interaction indicates the broad process of transition that is occurring and the role of the FIT within that.

Chapter 9 summarises the thesis and discusses the conclusions from the research. It addresses secondary research question 4 - How could policy be improved to further integrate the FIT technologies into the electricity system? It also directly addresses the central research question of this thesis - What is the role of the small-scale feed-in tariff in electricity system transition in the UK? The chapter outlines the empirical, policy-evaluation and theoretical contributions that the research makes and it proposes the potential areas of further research.

Chapter 2 – The Existing Electricity System and Barriers to Change

SECTION 2.1 CHAPTER INTRODUCTION

The previous chapter introduced the broad policy and research context and outlined the research questions that this thesis answers. This chapter explores that context in greater detail using academic, Government and industry literature. This provides a platform for the research and for the rest of the thesis. But it also shows how different elements within the electricity system are structured in a way that stabilises and incentivises large-scale incumbent technologies. It argues that small-scale RE faces a number of barriers to deployment that result from this structure of the system and that targeted policy support is therefore required to compensate for these barriers.

The chapter begins by explaining the physical infrastructure that underlies the existing electricity system and it outlines the dominance of large-scale thermal and nuclear plant and explains how the characteristics of RE technologies, and particularly small-scale RE, differ from this dominant configuration. Section 2.3 then outlines the benefits and disbenefits of small-scale RE. Section 2.4 discusses the way in which the industry has developed in the UK and the ownership structure that now exists. It indicates that this structure may be a barrier to alternative approaches because the existing large companies have an interest in maintaining the current configuration. Section 2.5 explains the institutional structure of the system and describes how this has developed. It discusses three main institutions and suggests that recent developments that have brought climate and energy policy together could open the possibility of more alternative approaches such as small-scale RE. Section 2.6 discusses the trading arrangements in the UK and shows how they are designed around large-scale plant. It goes on to outline recent proposals for changing the electricity market and argues that these may maintain a large-scale, centralised configuration. Section 2.7 discusses electricity investment practices and describes how the risks and costs of investment increase as project size decreases. The final section then provides a summary of the chapter.

SECTION 2.2 PHYSICAL INFRASTRUCTURE OF THE UK ELECTRICITY SYSTEM

The existing electricity system in the UK is a highly centralised network of mostly large thermal and nuclear generating stations feeding a high voltage (up to 400kV) interconnected transmission network which in turn feeds a low voltage distribution network that delivers power to end-users (Ofgem, 2008; Pepermans et al, 2005; Abu-Sharkh et al, 2006). These physical aspects of the system are collectively referred to in this thesis as the 'physical infrastructure'. Much of the existing system was designed and constructed by a state-owned monopoly utility[6] that owned and managed it from 1957 to 1989.

The primary objective driving the development of the system during this period was to generate as much electricity as possible, at least cost, in order to fuel the rapidly escalating demand of a growing economy. This occurred within a context of low-cost and abundant supplies of fossil fuels and with little knowledge, or concern, for the environmental implications (Helm, 2003; Scrase and MacKerron, 2009). Large-scale coal-fired and nuclear generating stations were the central pillars of electricity policy from the 1950s until 1990. During the early 1990s a number of factors combined to create a 'dash for gas' that brought many new gas plant online in a short space of time. The lifting of a European Community Directive in 1991 which prohibited burning gas in power stations, and the removal of some of the state support for coal-fired and nuclear power, which had maintained control pre-privatisation of the sector (discussed in detail below), paved the way for natural gas for generation. This was accompanied by technological developments in combined-cycle gas turbines (CCGTs) and the discovery of far greater reserves of North Sea gas than previously thought (Chick, 2007).

The current balance of generation can be seen in Figure 2.1 below. This shows the rapid rate at which gas fired generation developed to account for 40% (32 million tonnes oil equivalent) of fuel input for electricity generation in 2010. In addition to the factors outlined above, CCGTs were quickly built as they matched, and often improved upon, some of the

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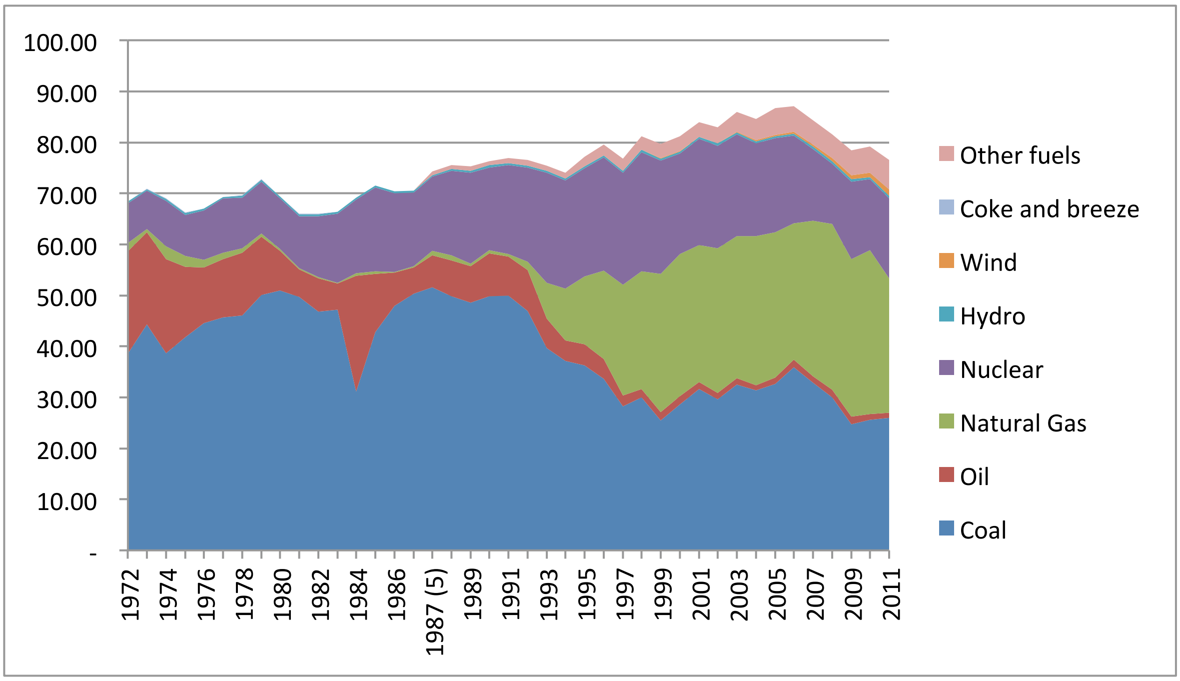
[6] In England and Wales this was the Central Electricity Generating Board and in Scotland was split between the South of Scotland Electricity Board and the North of Scotland Hydro-Electric Board.

characteristics of coal-fired plant. They are flexible, centralised, large scale[7] (although generally smaller than coal), thermal plant capable of generating large volumes without requiring significant changes to the existing infrastructure.

FIGURE 2.1 FUEL INPUT FOR ELECTRICITY GENERATION 1990 – 2011 (IN MILLION TONNES OF OIL EQUIVALENT)



Adapted from DECC (2011d)

It has been argued by many scholars that the current electricity system in the UK is, to a large degree, locked in to a large-scale, high-carbon, centralised configuration (Sauter and Bauknecht, 2009; Foxon et al. 2010; Scrase and MacKerron, 2009; Shackley and Green, 2007). As Foxon et al. (2010) state, '*the existing regime has acquired a (social) stability and inertia through the accumulated investments in existing technologies, infrastructures and institutions; consequently, most change is incremental, relatively slow and focused on maintaining the structure of the incumbent regime*' (2010, p. 1210),

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[7] The terminology 'large-scale' is used in three different cases in this thesis. Large-scale generation technologies refer to typical coal, gas or nuclear plant (500MW+). Large scale renewables refers in this thesis to projects over 5MW. Large-scale solar refers to projects above 1MW.

The longevity of generation plant (around 40 years for coal-fired stations) and transmission infrastructure creates large sunk investments that allow for only slow incremental change. The high capital costs of generation and transmission infrastructure encourage investors to maintain, rather than replace, their assets and maximise the period of return (Helm, 2003; Scrase and MacKerron, 2009). As the introduction of CCGTs shows, new plant can be added quickly, but this was only possible because it did not challenge the predominating centralised infrastructure. It was able to fit into the existing configuration within the network without stranding long running investments elsewhere.[8]

As 2.1 illustrates, renewable electricity capacity (‘Wind’ and an increasing percentage of ‘Other Fuels’) is increasing in the UK with 6.8% of total electricity in 2010 and 9.4% in 2011 (DECC, 2011d; DECC, 2012). Most renewable technologies display different characteristics to the conventional thermal and nuclear generating plant on which the system is currently based. Perhaps most notably they are diverse in terms of their sources, siting, scale and ownership (Bayod-Rujula, 2009). This does not align with the prevailing centralised configuration of the electricity system and this chapter argues that consequently there are a number of barriers to their deployment.

Another key characteristic of most renewable electricity technologies (excluding waste and biomass sourced plant) is that they are intermittent, or stochastic, in the way they generate. They are subject to the variability of the weather or tides and are therefore unable to follow the diurnal patterns of electricity demand. For example the output of solar PV systems will vary with the season, time of day, cloud cover and rainfall. Wind turbines are controlled by the wind speed, weather conditions and climate (Sovacool, 2009; Quiggin et al. 2012). Conventional generating stations are usually either baseload plant, that operate continuously to serve the minimum electricity demand with high load factors[9] (i.e. nuclear), or flexible load-following plant which can respond to variability in demand (i.e. coal and gas). These two generating plant types are predominant in the system and the network has

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[8] Note: Helm (2003) argues that the pace with which gas plant came online effectively priced some older coal plant out of the market. However, the transmission, distribution, nuclear and newer coal assets were not stranded by new gas generation.

[9] Load factor is a ratio of average output over theoretical maximum output over a period of time (usually a year).

developed around them. Thus the characteristics of RE technologies are an alternative to the dominant physical infrastructure of the electricity system. Small-scale RE technologies are even more removed from the technologies that dominate the existing system because they not only provide intermittent power, but also small volumes of generated electricity.

However, this thesis argues that small-scale RE has a number of benefits (see Section 2.3) that could have an important role in electricity system transition. Although they have alternative characteristics to the existing infrastructure, which implies a degree of disruption if they are deployed at scale, it is argued that the benefits to the system could be important in driving change. But as explained above, large-scale thermal and nuclear plant predominate and it is suggested that small-scale RE therefore requires targeted policy support in order to develop. The FIT provides this support and it is therefore important to explore the design and impacts of the scheme and how this has impacted on the electricity system as it currently exists.

SECTION 2.3 THE BENEFITS AND DISBENEFITS OF SMALL SCALE RE

Small-scale RE technologies represent a departure from the large-scale centralised technologies that predominate in the electricity system. With the exception of biomass, they have a number of characteristics that differ greatly from the characteristics around which the system has developed, as this chapter will discuss. These alternative characteristics present a number of challenges to adoption - primarily because they are different rather than because they are difficult to overcome - but also some inherent disbenefits. This thesis argues that there are also some important benefits of small-scale RE for a transition to a sustainable electricity system and these justify directed policy support. This section discusses the benefits and disbenefits of small-scale RE; it does not provide an exhaustive list but instead attempts to address the central issues raised in favour of, and against, small-scale RE.

SECTION 2.3.1 BENEFITS OF SMALL-SCALE RE

An advantage of small-scale RE is that it opens up the development of sites that are not suitable for larger scale RE, thereby maximising the available resource (Hain et al., 2005; Staffell et al, 2010). Solar PV, as an example, can be installed on domestic roofs where large-scale commercial development would not be possible. Developing down to this smaller scale could drive increased RE deployment and work towards the Government's RE targets (HMG, 2009a; DECC, 2009) (see Chapter 1 Section 1.3).

Deployment at this scale can also increase the investment capacity being directed towards RE because it creates an additional investment opportunity if appropriate policy support is provided. It also has the potential to access alternative economic actors to those who have traditionally invested in the electricity sector (Element Energy, 2008; DECC, 2009). These can include individual homeowners, farmers, community groups, businesses, and organisations that are able to bring new sources of finance into the energy space. This is a particularly important benefit at present due to the need to attract the huge investment required for a transition to low-carbon electricity system (see Section 1.3) (DECC, 2011a; DECC, 2009).

A technical benefit of small-scale RE is that network losses associated with the transmission and distribution of power can be reduced because small-scale RE technologies can be located close to demand sites. The closer the generating plant to the demand, the fewer the network losses will be and reduced losses translate to lower generation requirements on the system overall and therefore lower carbon emissions (Bayod-Rujula, 2009; DECG, 2012; Ofgem/BERR, 2008; Staffell et al., 2010).

In addition to reducing the network losses, small-scale RE plant can directly replace carbon intensive power that would otherwise be generated in thermal plant. This can reduce the carbon intensity of the electricity system by increasing the amount of renewable capacity feeding into the network (Bergman and Jardine, 2009; Watson et al., 2008). However, there is an issue here that relates to the intermittency of RE technologies and the requirement for reserve capacity to ensure that electricity supply is secure when intermittent technologies are not generating. This is discussed in Section 2.3.2 below.

One of the central advantages of a higher penetration of small-scale RE is that it increases the diversity of technologies on the network. This means that the system is supported by more energy sources and a more diverse supply chain. This can increase the resilience of the system to shocks affecting one technology or resource (Bergman and Jardine, 2009; Element Energy, 2008; Hain et al., 2005). For example, an electricity system that is built largely around gas plant is highly exposed to fluctuations in the price of natural gas. Further, if the supply of natural gas were to be stopped (for physical or geopolitical reasons) the system would falter. A more diverse system increases the resilience to these types of shock by spreading the risk across different technologies and resources. In addition, small-scale RE development is likely to increase the diversity of generating sites and points of connection to the network which further insulates the system from shocks at specific locations and increases it's resilience (Hain et al. 2005). This does also mean that the system is more complex, more difficult to balance because there are more units to account for, and potentially misses the economies of scale that large centralised plant can achieve. These issues are discussed in Section 2.3.2.

This chapter explains the elements of the existing electricity system that maintain its stability and frustrate the capacity for alternative options such as small-scale RE. One of the implications of a highly centralised system, such as the current system in the UK, is that the generation assets are owned by a very small number of vertically integrated companies (see Section 2.4). End-users therefore become merely consumers in that system because they are entirely reliant on those companies to provide electricity. Their only role is to use and pay for electricity (Devine-Wright, 2007; Watson et al., 2008). An advantage of small-scale RE is that it can introduce many more beneficiaries into the system if the individuals, farmers, community groups, businesses and organisations capable of developing projects choose to do so. This can widen control and democratise the system beyond the large electricity companies (IPPR, 2009; Devine-Wright, 2007; Devine-Wright and Devine-Wright, 2004).

Finally, there is growing evidence that situating generation close to demand centres can reconnect end-users with their energy use and significantly shift awareness, attitudes and behaviour relating to energy consumption and to the process of system transition. Dobbyn and Thomas found that –

> *'A whole host of attitudinal and behavioural shifts do seem to be fostered (though not automatically created) by the presence of on-site micro-generation. Some of our sample were only producing very modest levels of energy through their micro-generation technology, yet the behavioural impacts in terms of energy awareness and efficiency were often still considerable' (Dobbyn and Thomas, 2005, p. 10).*

Energy behaviour is a complex issue that is affected by many factors. Studies by Dobbyn and Thomas (2005), Keirstead (2007), IPPR (2009), and a joint report by the Cabinet Office, DECC and the Department for Communities and Local Government (Cabinet Office et al. 2011) indicate that a positive energy-behavioural response can occur in response to micro- and small-scale generation. However, this is often reliant on the quality of information the generator receives on installation, and indeed the performance of the technology itself (Bergman and Jardine, 2009). This will be discussed in the following section which addresses the disbenefits of small-scale RE.

SECTION 2.3.2 DISBENEFITS OF SMALL-SCALE RE

One of the central criticisms of small-scale RE technologies is that they produce a small amount of power relative to their cost (Bayod-Rujula, 2009; Allen et al. 2008). Certainly the up-front capital costs can be prohibitive for many potential generators and policy support is required to ensure a return is made on investment. There are two principal reasons for this. The first is that sub 5MW generation cannot achieve significant economies of scale because many more small-scale generating units are required to achieve the same output as one large generator. There are fixed costs associated with each technology and installation, and small-scale technologies have limited scope for reducing these fixed costs in relation to the output or return from the generation. The second reason is that deployment levels of small-scale technologies have not been high enough, particularly in the UK pre-FIT, to drive down their costs. Before the FIT was introduced the market was uncompetitive which allowed manufacturers and installers to maintain high profit margins and inflate the cost of installation (Bergman and Jardine, 2009; National House Building Confederation Foundation, 2008; Watson et al., 2008).

Another central issue concerning the viability of small-scale RE is the intermittent generation they provide. The technologies are reliant on weather patterns that are mostly predictable but do not always coincide with periods of demand (Quiggin et al., 2012; Bayod-Rujula, 2009). This is particularly prevalent for domestic technologies in terms of meeting the demand of the property because domestic demand is highly variable and unpredictable at the house level (Staffell et al. 2010). Matching this stochastic demand is more straightforward when averaged out across the electricity network, which is an advantage of a centralised system. Optimising the use of domestic RE technologies requires managing the demand of the property in response to the generation provided by the technology (Quiggin et al., 2012). This has not been a necessary requirement under the existing centralised system and end-users have become used to having power when it is required. However, the engagement and learning required to consider how to optimise a domestic RE system could also be a major benefit of small-scale RE in terms of the educational platform it provides (Bergman and Jardine, 2009).

The issue of intermittency also relates to a further criticism of small-scale RE technologies; their incompatibility with the existing electricity network. At present the electricity system predominantly takes power from large generation plant, transports it in bulk at high-voltage levels, distributes it to the lower voltage distribution network which then delivers power to end-users. The distribution networks are passive and radial at lower voltage levels, designed to accept power from transmission systems and distribute to customers, generally with unidirectional flows (Bayod-Rujula, 2009). Distribution Network Operators (DNOs) conduct limited management beyond ensuring that the networks stay within technical limits (Woodman and Baker, 2008). The introduction of small-scale RE to the network requires that the network is more actively managed because additional capacity I being added at a point in the network designed merely to distribute power. The level of control required to manage this new generation requires a degree of upgrading, reinforcement or replacement of the network and this has associated costs.

However, Woodman and Baker (2008) argue that upgrades to the distribution network are required anyway –

'The Energy Networks Association (2005) estimates that around 70% of the UK's network assets are now reaching the end of their design lives, and there is a general consensus that provision has to be made to finance a programme of network upgrades and replacements. There is therefore an opportunity to substitute 'like for like' replacement of infrastructure with new technologies which could enable more active management' Woodman and Baker, 2008, p.4529)

Despite the need for upgrades to the existing network, the requirement for more active management to control new small-scale capacity is an additional issue to be considered in balancing the value of small-scale RE for electricity system transition.

Finally, a contentious aspect of small-scale RE development is the aesthetic impact that multiple installations can have on an area. Centralised power plant make a huge impact on the areas in which they are built but these are generally remote from population centres and there are relatively few of them because they generate such large volumes of power. Small-scale RE provides capacity in many more numerous individual units dispersed across a far wider area. This has implications in terms of the acceptance of small-scale RE and there are often difficulties with receiving planning permission for new development (Watson et al., 2008; Devine-Wright, 2007). This is a further consideration in balancing the appropriateness of small-scale technologies against large-scale centralised plant.

SECTION 2.3.3 BALANCING THE BENEFITS AND DISBENEFITS OF SMALL-SCALE RE

There are both advantages and disadvantages to small-scale RE development and balancing, these depend on the value placed on each of the issues discussed in Section 2.3.1 and 2.3.2. The advantages of small-scale RE include maximising the available RE resources; widening the electricity investor base; reducing network losses; reducing the carbon intensity of the electricity system; increasing the diversity of the system and therefore its resilience; democratising the system; and a positive impact on energy behaviour. Against these potential benefits are the high costs associated with small-scale RE technologies relative to the volumes of power they generate; the intermittency of the technologies against stochastic domestic demand; the incompatibility of small-scale generation with the existing network; and the aesthetic impact of multiple small-scale installations.

This thesis argues that the benefits of small-scale RE are sufficient to justify directed policy support. It does not suggest that large scale technologies are not required but rather that a diversity of technologies is needed to decarbonise the electricity system and this goal warrants addressing the challenges outlined in Section 2.3.2. The principal reason for this is the increased diversity that small-scale technologies provide for the electricity system. The portfolio approach to electricity that the UK Government have proposed is important given the scale of the challenge that climate change presents (DECC, 2011h). If the electricity system is to be decarbonised by 2030, as Government documents have indicated is the intended policy goal (e.g. DECC, 2011a; DECC, 2011b), then a wide-range of different technologies will need to be deployed. It is not yet known what balance of technologies will make-up the system in 2030 or beyond but by encouraging diversity now, there is the greatest chance of finding an optimal balance. This is illustrated by the following quote from the Carbon Plan -

'In the 2020s, we will run a technology race, with the least-cost technologies winning the largest market share. Before then, our aim is to help a range of technologies bring down their costs so they are ready to compete when the starting gun is fired' (HMG, 2011, p.3).

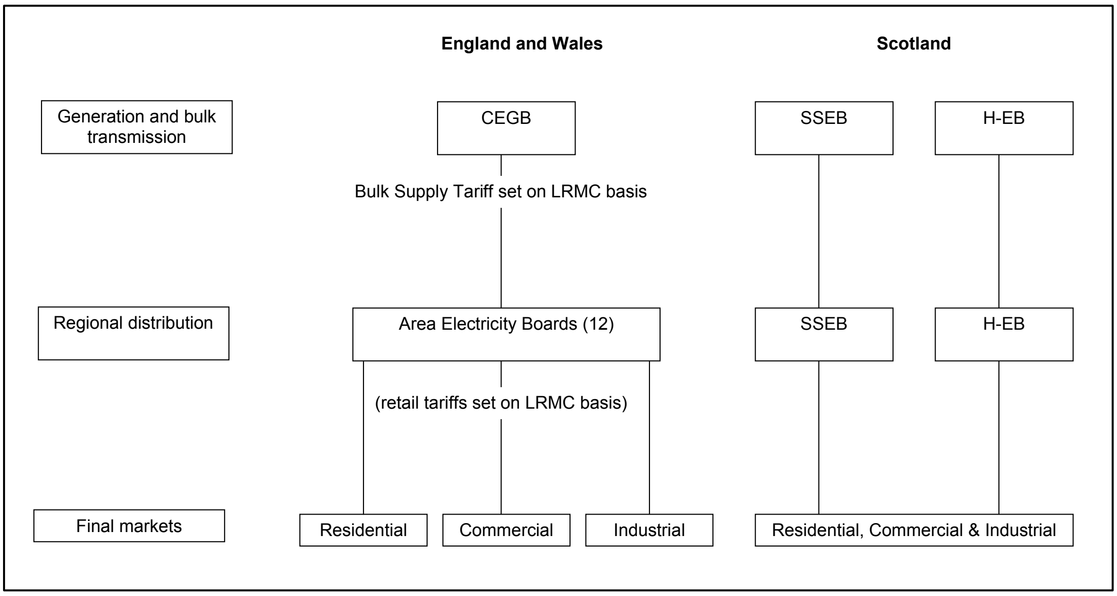
The remainder of this chapter will outline the reasons why the existing system in the UK is locked-in to a centralised, high-carbon pathway. This explains why alternative approaches, such as small-scale RE, are frustrated from being developed.

SECTION 2.4 INDUSTRY OWNERSHIP AND STRUCTURE

The inertia of the electricity system that Foxon et al. (2010) (see previous section) and others have described is in part caused, but also maintained, by the structure of the industry itself. This structure has resulted from the development of the industry from state monopoly, through the privatisation of the sector, and up to the present day. This section explains these developments and discusses the implications for small-scale RE.

Until 1989 electricity in the UK was a nationalised industry. In England and Wales the industry was dominated by one large state-owned generation and transmission company, the Central Electricity Generating Board (CEGB), which sold power to 12 area distribution boards, each of which supplied power to a closed supply area. In Scotland, there were two vertically integrated boards that had regional monopolies, but co-operated closely in the use of their generating plant (DECC, 2012n; Simmonds, 2002). This pre-privatisation structure is illustrated in Figure 2.2 below.

FIGURE 2.2 STRUCUTRE OF THE ELECTRICITY INDUSTRY PRE-PRIVATISATION

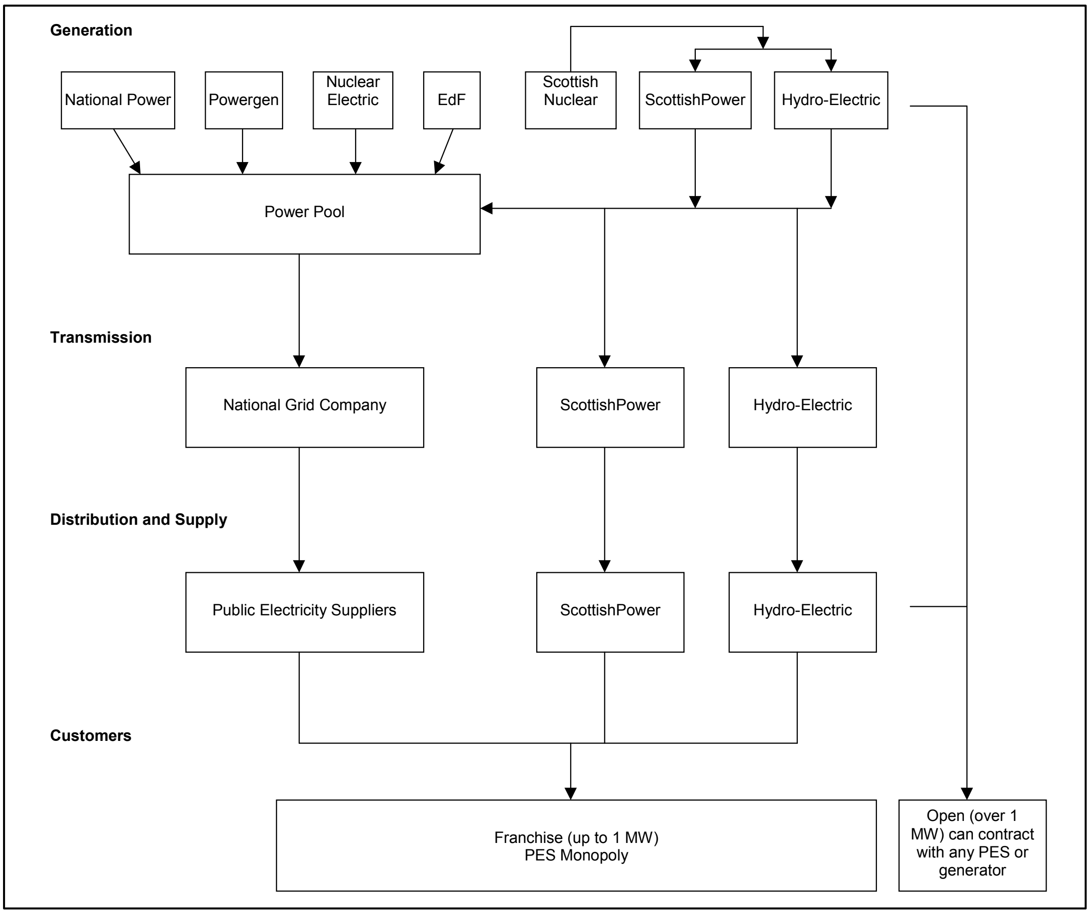


(Source: Simmonds, 2002).

As part of a wider privatisation programme under Margaret Thatcher, the Electricity Act 1989 laid the legislative foundations to privatise the electricity sector and open the wholesale and retail markets to competition (Carter 2001; Foxon et al 2005; Helm, 2003; Mitchell 2008; Ofgem, 2003; Scrase & McKerron, 2009). The subsequent 8-year transition (March 1990 to May 1999) began by restructuring the industry in order to ensure that a public monopoly was not merely transformed into a private monopoly.

The new structure was introduced on 31 March 1990 and it split the CEGB into three generating companies (National Power, Powergen and Nuclear Electric) and a transmission company (National Grid Company). The 12 area boards were replaced with regional electricity companies (RECs) who each took control of a local distribution network and became the monopoly supplier on that network. Initially, the 12 RECs collectively owned the National Grid Company. In Scotland the two electricity boards were replaced by ScottishPower, Scottish Hydro-electric and Scottish Nuclear Electric. (DECC, 2012n; Ofgem, 2008; Chick, 2007; Simmonds, 2002; Helm, 2003). A system of independent regulation was created, initially headed by the director general of electricity supply, covering England, Wales and Scotland, and supported by a regulatory office, the Office of Electricity Regulation (OFFER) (DTI, 2003; Ofgem, 2003). In addition, an electricity pool was created which was a system through which generators had to offer wholesale electricity, and from which those who wanted to purchase wholesale electricity had to buy (see Section 2.5). The industry was restructured in this way to allow for a controlled privatisation programme. The industry structure at privatisation is illustrated in Figure 2.3 below.

FIGURE 2.3 STRUCUTURE OF THE ELECTRICITY INDUSTRY AT PRIVATISATION



Source: Simmonds (2002). Note: EdF sold power into the pool via an interconnector from France. Public Electricity Suppliers/PESs in this diagram are the RECs.

The companies formed in the restructuring illustrated in Figure 2.3 were sold off gradually through the 1990s. This began with the public flotation of the 12 RECs in December 1990 although the Government retained a special share that prevented any other investor from buying more than 15% of the shares for a period of five years. 60% of the shares in Powergen and National Power were floated in March 1991 and in June 1991 Scottish Power and Scottish Hydro-electric were sold. The Government retained ownership of the two nuclear companies at this stage (DECC, 2012n).

In March 1995 the remaining 40% of shares in Powergen and National Power were sold and the Government's special share in each of the privatised supply companies expired which opened the companies to the potential for acquisitions and mergers. In December 1995 National Grid was floated (DECC, 2012n).

In March 1996 the nuclear industry was restructured to enable a partial privatisation. Nuclear Electric and Scottish Nuclear became subsidiaries of the newly formed British Energy and this was then floated in July 1996 with control of the 8 most advanced nuclear plant in the UK. However, the older Magnox stations remained in public ownership with Magnox Electric which later merged with the state owned British Nuclear Fuels Limited.

Competition in the supply market was introduced in three stages -

1. April 1990 - customers with peak loads of more than 1 MW were able to choose their supplier;
2. April 1994 - customers with peak loads of more than 100 kW were able to choose their supplier;
3. September 1998 to May 1999 – customers with peak loads of less than 100kW were able to choose their supplier.

The opening of the supply market to full competition was seen as the final act in the privatisation project (DECC, 2012n; Ofgem, 2008; Simmonds, 2002; Helm, 2003). Up to this point there had been many changes in supply business ownership but the structure remained largely stable. However, despite initial reluctance, OFFER, which was replaced by the Office of Gas and Electricity Markets (Ofgem) in 1999, allowed the consolidation of the electricity industry between 1998 and 2002. A number of mergers reduced the incumbent suppliers created at privatisation as large energy companies bought up supply businesses to increase their customer base (Ofgem, 2008b). Also, the large companies began tentatively to vertically integrate by buying generation assets which would later allow them to bypass the electricity spot markets and effectively contract with themselves (Chick, 2007).

This concentrated market has become six vertically integrated energy companies – commonly referred to as the Big 6.[10] These Big 6 supplied approximately 96% of UK electricity in 2011 and generated between 71.3% of electricity in the same year (Ofgem, 2012e). This development has profoundly influenced the capacity for change within the electricity sector today by concentrating control of the market into a few large companies. These companies have built their businesses upon a centralised, large-scale foundation and they hold considerable assets and liabilities that depend on those investments remaining valuable (Stenzel and Frenzel, 2008). It is therefore unclear whether small-scale RE, in representing an alternative to that foundation, is in the interests of those Big 6 companies to deploy at significant scale and this thesis therefore argues that policy support is required to drive the deployment of these technologies. Whether this encourages the Big 6 to develop small-scale RE, or whether it introduces new market entrants, the thesis argues that the benefits of small-scale RE (see Chapter 2 Section 2.3) would not be realised within the existing industry structure without policy support. The dominance of the Big 6 energy companies also has consequences for the trading of renewable power, which is discussed further in Section 2.5.

The degree of success and the costs of privatisation are contested within the academic literature (e.g. Thomas, 2006; Pollitt and Bialek, 2008) but it is widely accepted that the environmental, economic and resource context within which the electricity system operates has changed since the 1990s when privatisation occurred (DECC, 2011; Scrase and MacKerron, 2009; Smith, 2009; Mitchell, 2008; Grubb et al. 2008). A new context has emerged with concerns over energy security and climate change. This in turn has shifted the

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[10] The Big 6 includes EDF, E.ON, RWE npower, Centrica, Scottish Power (owned by Iberdrola) and Scottish and Southern Energy.

objectives of electricity policy and it is unclear whether the way in which the industry is currently structured is able to respond to this new direction. This thesis argues that this is part of the reason why a FIT is required in the UK; because small-scale RE, and the benefits it has for the new context of electricity, may not be developed at scale by the existing industry without the incentive the FIT provides.

SECTION 2.5 INSTITUTIONS

In addition to the structure of the electricity industry, the institutions that have steered the sector through its development are a critical element in understanding the barriers to alternative approaches, and also for the potential for change. The following section outlines the institutional developments that have followed privatisation of the sector, discussed in the previous section. The key institutions covered in this section are Ofgem, DECC, and the Committee on Climate Change (CCC). The section discusses the role of Ofgem and then goes on to show how energy and climate policy has been brought together with the recent and potentially positive introduction of DECC and the CCC.

Prior to privatisation the electricity industry was managed by the Department of Energy but in 1992 it was disbanded. Blackhurst (2004 in Kuzemko, 2009, p. 5) suggests this was because, in Margaret Thatcher's view, '*(it) smacked of economic planning … whereas our energy needs should be supplied by the market'.* Energy, and electricity, policy was passed to the Department for Trade and Industry (DTI) and later the department for Business Enterprise and Regulatory Reform (BERR), whose principal role was to provide support and regulation for British businesses. This downgrading of energy policy to a department within a department reflected a view that energy was seen as a sub-sector of the wider economy and that as such it could be left to market forces, with some appropriate regulation, to decide the best direction. As Smith (2009) discusses, the role for DTI, BERR and Ofgem was to *allow* the electricity industry to develop into an efficient and profitable business sector and it was not the job of Government to make decisions about energy sources or technologies. These institutions were supposed to be 'fuel blind' and tried to avoid 'picking winners' (DTI 2003; DTI 2007; Mitchell 2008).

SECTION 2.5.1 OFGEM

Ofgem has played an increasingly central role in the electricity system since it took over from OFFER in 1999 (DECC, 2011i; NAO, 2012; Mitchell, 2008). This section explains how the regulator has evolved to allow greater consideration of factors beyond incentivising cost reductions and the impact that this has on the small-scale RE sector.

Initially Ofgem was an economic regulator whose primary role was to set price controls for monopolies and promote competition where possible (DTI, 2003). This was changed shortly after it was created to put consumer interests at the centre of its decision-making and its primary duty became to protect the interests of consumers, wherever appropriate by promoting competition (Owen, 2004; Ofgem, 2008). Ofgem's remit has widened since this point as it has become the body responsible for administering a number of initiatives including the RO, the Climate Change Levy, the Carbon Emissions Reduction Target and more recently the FIT (DECC, 2011i). It has also adopted a role developing energy policy, for example with the policy options set out in their "Project Discovery" report which looked at reforming British energy markets in order to secure supplies and help meet climate change targets (Ofgem, 2010; NAO, 2012).

The 2004 Energy Act introduced sustainable development as a new goal for Ofgem and the 2008 Energy Act extended this to make it a formal duty. Ofgem's role in protecting consumers has also developed so that '*their interests (are) taken as a whole, including their interests in the reduction of greenhouse gases and in the security of the supply of gas and electricity to them* (Ofgem, 2012d; p.1). The definition of interests has therefore extended beyond cost reductions and Ofgem has had to evolve in order to respond to this changing role.

The Sustainable Development Commission reviewed Ofgem's role in 2007 and found that it had succeeded in driving down the price of energy, improved the efficiency of energy companies, and it had provided a stable business framework for the industry (SDC, 2007). But it also found that Ofgem was not designed to facilitate the radical changes required to decarbonise the electricity system and work towards sustainable development. They therefore recommended that Ofgem's duties should change to specifically integrate emissions reductions.

Also, in the recent Ofgem Review DECC indicated that –

> *'When the process for privatising the gas and electricity sectors began in the 1980s, and economic regulation first established, the focus was on meeting consumer interests by seeking greater efficiencies, which would be reflected in consumers' energy bills. In the subsequent decades, there have been substantial shifts in the policy landscape, which mean that the energy sector, and so the energy regulator, is now expected to contribute to a much broader range of public policy goals'* (DECC, 2011i, p.10).

With a central responsibility to protect consumers by keeping costs low, Ofgem can be conflicted in facilitating the development of alternative electricity options that cost more than the existing technologies; a development that is required to decarbonise the system (DECC, 2011a). As discussed in Chapter 1, electricity technologies tend to achieve increasing returns to cumulative adoption which means it may be cheaper for consumers in the short-term if more large-scale thermal plants are built. Ofgem's role in protecting consumers has developed to include responsibility for future, as well as present consumers and there is therefore a conflict in balancing short-term costs with long-term objectives.

Woodman and Baker (2008) argue that there is a considerable degree of discretion required by Ofgem to balance its duties and this could result in alternative small-scale options not being duly considered or promoted. They conclude that '*the regulatory framework will have to evolve to enable rather than restrict the deployment of small-scale, sustainable technologies and to permit new business models which reward increased carbon or energy efficiency'* (Woodman and Baker, 2008, p. 4530). Ofgem have an important role in interpreting Government policy and setting the framework of rules and incentives within which the electricity industry must act. They are therefore able to drive or limit investment in the electricity system through the use of their statutory powers, but it is not yet clear how they will balance their duties going forwards (Mitchell, 2008). This could have significant implications for the investment in and deployment of small-scale RE. However, as will be explained in Chapter 5, the FIT insulates small-scale RE from the electricity market and so limits the powers that Ofgem have to influence it. They administer the scheme, and have a central role in the system in general, but DECC have primary responsibility.

SECTION 2.5.2 THE COMMITTEE ON CLIMATE CHANGE AND THE DEPARTMENT OF ENERGY AND CLIMATE CHANGE

The UK's share of the EU 20:20:20 program, discussed in Chapter 1 Section 1.3, was a target of 15% of total energy to come from renewable sources by 2020. Due to the technical, political and socio-cultural difficulties associated with renewable heat and transport (see Chapter 1 Section 1.3) 30% of generated electricity is required to come from renewable sources, up from 6.8% of total electricity in 2010 (HMG, 2009a; HMG, 2009; DECC, 2011d). This is significant, not only in terms of the scale of the challenge posed by the targets but also by bringing together energy and climate policy under legally binding targets for the first time in the UK. For the institutions involved with delivering these targets it has had a profound impact on the objectives of energy and electricity policy and the degree of intervention required to achieve those objectives (Ofgem, 2008; HMG, 2009a; HMG, 2011; DECC, 2011a).

In addition to the European targets, the Climate Change Act of 2008 set a legally binding carbon dioxide emission reduction target of at least 80% by 2050. This is to be achieved through the setting of five-year carbon budgets across Government and is to be monitored by the newly created CCC. The CCCs role is '*to advise the Government on emissions targets, and to report to Parliament on progress made in reducing greenhouse gas emissions*' (CCC, 2012). The committee has been a vocal institution since it was set up, sometimes critical of Government policy (e.g. CCC, 2011), and directly linking climate change and energy policy (e.g. CCC, 2011a). It has also created an additional voice within the energy policy-making process, pitched between Government and the Big 6. This has institutionalised climate change within a decision-making process that has largely been conducted by the same companies who benefit from the existing system (see Section 2.3). Before the CCC were introduced this role was filled by independent consumer groups, non-governmental organisations and the Sustainable Development Commission but these organisations did not have the legislative provision created by the 2008 Climate Change Act and therefore did not have the same level of influence over governmental policy. The degree to which the CCC are able to shape energy policy is still influenced by Government, the industry and other organisations but the existence of cross-departmental carbon budgets and a statutory counter-voice to business-as-usual policy-making suggests that the governance of energy, electricity and climate change *could* be becoming more open and progressive.

The linkage between climate change and energy policy has also been expressed in the forming of DECC which brought together the energy policy duties of the DTI/BERR and the climate change mitigation policy previously with the Department of Environment, Food and Rural Affairs (DEFRA). DECC's first two documents were '*The UK Low Carbon Transition Plan'* (HMG, 2009a) and the '*Renewable Energy Strategy'* (HMG, 2009) both of which addressed the role of Government in meeting policy objectives. These two documents, and further documents published by DECC, appear to show a shift in the belief in the capacity for market forces to deliver energy, and electricity, goals. The Electricity Market Reform consultation which was released in December 2010 illustrates this new thinking underlying policy-making at DECC –

> *'Our electricity market has served us well, providing affordable and secure energy since the 1990s. The watchword has been the encouragement of competition overseen by Ofgem as the independent regulator of the sector. As a result we have had some of the lowest electricity prices in the EU and this model formed the basis for EU rules on energy markets and independent regulation. However, in the coming decades we face major new challenges which require careful but far-reaching reforms to meet our objective of ensuring the supply of reliable, low carbon and affordable electricity' (DECC 2011a, p. 4).*

The formation of DECC and the CCC could be seen as a significant development in the institutional governance of energy and climate change in the UK. The linking of climate change and energy policy, and an acceptance that direct departmental intervention is required to achieve policy objectives, follows long-standing calls from academic and environmental research (e.g.Scrase et al. 2009; Carter, 2001; Mitchell, 2008; Kuzemko, 2009; Greenpeace, 2006). However the efficacy of these institutions, and Ofgem, to deliver change within the electricity system is still framed by a wider political and economic context as well as the inertia within the other elements of the electricity system discussed in this chapter. It is also unclear how far the Government are prepared to intervene in the electricity market to achieve their goals, despite recent announcements, and this could have profound implications for the degree and direction of change, and for the role of small-scale RE (Kuzemko, 2009) (see Chapter 9 Section 9.4).

The institutional framework in the UK has had an important impact on small-scale RE because post-privatisation the role of the various regulators and policy-makers has been to facilitate the industry to deliver the most efficient service to end-users. This has resulted in the creation of the industry structure described in Section 2.3, which in turn has impacted on the physical infrastructure described in Section 2.2. As discussed above, this is mostly based on large-scale technologies and small-scale technologies are not widely deployed. But this thesis argues that a transition to a sustainable electricity system should involve small-scale RE due to the benefits outlined in Chapter 1 Section 1.5. The institutional framework for the electricity system has a critical role in whether small-scale RE is deployed through regulation and policy and this framework has changed in recent years in response to new drivers such as climate change. The way in which DECC, the CCC and Ofgem balance the drivers of electricity is thus an important factor in the role of small-scale RE in system transition.

SECTION 2.6 MARKET DESIGN AND TRADING ARRANGEMENTS

Renewable energy projects have high up-front capital costs but relatively low operational and fuel costs compared to thermal and nuclear plant. This means that it is particularly vital for the economics of a renewable project that they are able to sell their power (offtake) in order to recoup the early investment. However, as this section explains, the existing trading arrangements in the UK were designed for conventional large-scale generators and selling power is a complex and uncertain process. The section details the trading arrangements that exist, explains what difficulties they create for renewable generators and moves on to assess the appropriateness of the recent Energy Bill for RE investment and generation.

The privatisation of the electricity industry was an extremely complex process both logistically in terms of restructuring the industry, but also in creating a market through which electricity could be traded (Helm, 2003). Electricity is unlike most commodities in that it cannot easily be stored and a market is therefore required that maintains a balance between supply and demand at all times. Initially after privatisation all generation in England and Wales was sold into a 'gross', or 'compulsory' pool, receiving a uniform pool (marginal) price, and dispatched centrally by the System Operator. However the Pool was criticised for not fostering adequate competition, distorting the power price and for allowing a concentration of market power (Green, 2003; Helm, 2003). The regulator, OFFER, reviewed the trading arrangements and highlighted problems with market manipulation, market design, and the governance structure. The final proposals of OFFER's *Review of the Electricity Trading Arrangements* were published in 1998 and recommended far-reaching reforms (OFFER, 1998; OFFER, 1998a). Subsequently the trading arrangements were reformed in 2001 and the New Electricity Trading Arrangements (NETA) were introduced.

NETA was designed to reduce costs through greater competition and to incentivise generators and suppliers to balance their own position through long-term futures contracts and short-term bilateral trading (Ofgem, 2011). The system operator, National Grid, is required to manage any imbalance between demand and supply through the Balancing Mechanism and to settle any difference between contractual positions and actual physical flow after the power is delivered (Imbalance Settlement). NETA was extended in April 2005 to cover Scotland under the British Electricity Trading and Transmission Arrangements (BETTA).

BETTA was designed to support large, centralised, predictable thermal and nuclear generation (ECCC, 2011; Woodman and Baker, 2008; Chick, 2007). It therefore rewards generation that meets these characteristics to the detriment of alternative generation types such as RE and small-scale technologies. The Energy and Climate Change Select Committee report on Electricity Market Reform (EMR) evidenced a quote from Good Energy suggesting that "*existing renewable generation is there in spite of the market structure, not because of it*" (ECCC, 2011, p.14). The following points are potential issues for renewable generators operating in this market -

- *Transaction costs:* The transaction costs associated with trading through BETTA are blind to the volume of power to be traded. This incentivises large clip-sizes[11] because the costs per unit are reduced with greater volume. Smaller clip-sizes are thus penalised which is an unavoidable cost for smaller or intermittent generating plant (Woodman and Baker, 2008).
- *Unduly high imbalance exposure:* Intermittent generators also have a higher exposure to imbalance penalties through the Balancing Mechanism due to the difficulties of accurately forecasting their output. The penalties vary in severity and timing depending on the rest of the market but it is the exposure to uncontrolled additional costs that raises the risk profile of renewable generation (Hesmondhalgh et al. 2010).
- *Lack of a liquid market:* Due to the high degree of vertical integration in the electricity industry the wholesale market is illiquid meaning the products and volumes available on the power exchanges are limited (Ofgem, 2012). Also, there is no separate trading point for renewable electricity, which displays unconventional characteristics, and it is therefore difficult for generators to value and/or sell their power themselves. This means independent renewable generators will usually contract bilaterally with suppliers, often negotiating a Power Purchase Agreement (PPA) which will include an imbalance risk premium within the PPA to compensate for the intermittency of the power. This can reduce the price per unit of power for the generator and it can be a complex and expensive negotiation for smaller generators (Hesmondhalgh et al. 2010).
- *High operating costs:* intermittent generators need access to sophisticated, expensive forecasting services in order to reduce their imbalance exposure. They also, if engaging in the market, require full-time trading desks and they must become signatories of the Balancing and Settlement Code which is the governance arrangements for electricity balancing and settlement in Great Britain. This presents an additional fixed cost that can be a burden for smaller generators (Hesmondhalgh et al. 2010; Ofgem, 2010; Woodman and Baker, 2008; ECCC, 2011).

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[11] Clip-size is the size of a contract to be traded

- *Offtake risk:* There is no guarantee of offtake for renewable power under BETTA. This creates an inherent risk for small generators that they will be unable to find a long-term buyer for their power without a PPA. This significantly affects the risk profile of a renewable project which will in turn raise the cost of capital.
- *Power price risk and fluctuation*: CCGTs, and sometimes coal, are the marginal (price setting) plant in the UK market[12]. Fuel costs are a significant factor in the generation costs for those plant and the market price of power therefore tends to fluctuate with the price of gas or coal. Most RE technologies have no fuel costs and they are therefore 'price takers.' This means they are subject to fluctuations in the power price which are beyond their control. This raises the risk profile of renewable electricity investment (DECC, 2011c).

These issues have been widely debated within the electricity industry and in the academic literature since the introduction of NETA in 2001 (Helm, 2003; Woodman and Baker, 2008; ECCC, 2011; E.ON, 2002). The outcome of these issues is that investment in RE, and particularly small-scale RE, has been a complex, high-risk process that has favoured large established companies who can finance RE projects from their own balance sheets and roll them up into a wider portfolio of investments to spread the trading risks outlined above (Stenzel and Frenzel, 2008; DECC, 2011c). This has maintained the central role of the incumbent utilities and disincentivised independent, innovative, new market entrants, and it has also resulted in mainly large-scale RE projects being delivered. However, this is also a result of the design of the Renewables Obligation (RO) which is the principal support mechanism for RE in the UK (Agnolucci, 2007). The impact that the design of the RO has had on RE deployment is explained in Chapter 5 Section 5.3.1.

This section is suggesting that the trading issues that are discussed above exist because NETA/BETTA was designed around the large-scale plant that dominates the electricity system. Small-scale RE generators face a number of issues in selling their power because they have alternative characteristics to the predominant generators which ultimately

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[12] Different power stations have different generation costs. In balancing daily demand in the electricity market, the system operator will take capacity, starting at the lowest-cost option, until demand is met. The price of power at the point where demand is met becomes the market price for all power stations. The plant that this last unit is taken from is the marginal plant.

disincentivises development at the smaller scale (DECG, 2011). This thesis argues that for this reason small-scale RE requires policy support to ensure that generators can sell their power, and that they are not excessively penalised for selling small volumes. The next section explains how recent proposals for reforming the electricity market are not likely to fundamentally change the problems identified above for small generators.

SECTION 2.6.1 PROPOSED CHANGES TO THE MARKET – ELECTRICITY MARKET REFORM

Some aspects of the electricity market have been considered as part of the Electricity Market Reform (EMR) process that has been running since December 2010, culminating in the Energy Bill published in November 2012. As this section will explain, the measures within the Energy Bill are maintaining a preference in the market for large-scale technologies. The EMR consultation document stated that –

> *Without reform, the existing market will not deliver the scale of long term investment, at the pace that is needed, nor will it be able to ensure that consumers get the best deal. If we are to meet our long-term carbon and security of supply objectives, we need to reform the market now, and make investment in low-carbon generation in the UK more attractive* (DECC, 2011b).

The White Paper that resulted from the EMR consultation proposed a package of reforms consisting of four policy instruments -

1. Contracts for difference (CfD) for low-carbon generators;
2. An emissions performance standard which sets an annual limit on the permissible carbon emissions from generating stations;
3. A Carbon Price Floor which tops up the EU Emissions Trading System (EUETS) carbon price for the electricity generation sector;
4. A Capacity Market with auctions for generators to build or provide capacity, storage and demand side response that is required to ensure security of supply (DECC, 2011b; DECC, 2011c).

The Carbon Price Floor was confirmed by Treasury in the 2011 Budget and will be introduced from April 2013. The other three instruments were confirmed in the Energy Bill introduced in November 2012. These instruments are designed to compensate or incentivise low-carbon generators and those providing ancillary support necessary to a low-carbon electricity system (e.g. back-up or peaking thermal plant) (DECC, 2011b). The CfD will replace the RO in 2017 for new entrants and it is a system of long-term contracts between a low-carbon generator (nuclear, renewable and coal/gas with CCS) and a counterparty that will provide a fixed level (strike price) under which variable payments are made. The payments are the difference between a market reference price and the strike price. The CfD payment is made in addition to the generators revenues from selling power through the existing market arrangements. If the reference price exceeds the contracted strike price the excess must be returned to the counterparty (DECC, 2011a and 2011b).

There are many arguments surrounding the various mechanisms as they have been debated throughout the EMR process. The central concerns for RE generators, particularly at the smaller scale, are related to the complexity of the CfD, the remaining offtake risk within the market and the uniformity of support across different clip-sizes -

- *Complexity* – the CfD payments a generator will receive will vary according to the market reference price, which for baseload generators is set by an averaged year-ahead price and for intermittent generators is set by the day-ahead market price. Payments for intermittent generators will also vary according to the administratively set strike price. This variability creates complexity for generators in predicting their revenue and it still requires sophisticated forecasting and trading services to minimise imbalance exposure. This can be particularly burdensome for small and new generators in the market (DECG, 2011; Mitchell et al. 2011).
- *Offtake risk* – The EMR mechanisms do not remove the requirement for generators to find a buyer for their power. They must still contract directly with a supplier or sell into the trading markets. Due to the lack of liquidity in the trading markets many renewable generators negotiate PPA's with suppliers. As stated above, PPAs typically include a risk premium to cover the imbalance exposure taken on by the supplier when they contract intermittent power. This means the generator receives a reduced price for their power which is likely to be below the market reference price. There may therefore be a shortfall for generators with a PPA. DECC and Ofgem are

working to address liquidity (DECC, 2011b; Ofgem, 2012) in the wholesale market which, if successful, could improve the option for renewable generators to sell their own power through increasing the diversity of clip-sizes that are bought from the market and therefore reduce the necessity for PPAs. However it is not yet clear how successful these interventions will be or whether they will improve the prospects for generators at the smaller scale.

- *Uniformity of support* – As discussed above, BETTA does not differentiate for different clip-sizes. This effectively incentivises large bulk sales of power because the transaction costs are reduced per unit. Thus, smaller generators are put at a disadvantage. The CfD amplifies this disadvantage because the payments made to all intermittent generators are based on the day-ahead price. A small generator selling small clip-sizes will thus incur higher transaction costs per unit or reduced PPA revenue, but the same CfD payment as any other generator (DECG, 2011; Mitchell et al. 2011; ECCC, 2011).

Thus the EMR, despite being a significant intervention into the electricity market, can still be argued to be maintaining the dominant centralised approach to electricity generation. Some of the analysis that underpinned the Planning our Electric Future White Paper Impact Assessment stated that '*in order to meet agreed low carbon targets, the required investment in generation, in our view, is predominantly likely to take the form of large scale offshore wind and nuclear – which form the main focus for our report'* (CEPA, 2011, p. 5). It does not mention small-scale, distributed or decentralised energy, or consider their unique characteristics. Its analysis is focused on centralised plant and this thesis argues that the design of the mechanisms proposed in the White Paper reflect this focus and will work predominantly for generating plant matching those characteristics.

As this section has shown, the trading arrangements in the UK are designed around the large-scale technologies that dominate the existing system. RE technologies have a number of characteristics that differ from thermal and nuclear plant and they are therefore effectively penalised. Small-scale RE technologies face even more acute problems in selling their power because the market favours bulk sales. The EMR proposals are still being developed but they also appear to be weighted towards large-scale low-carbon technologies. This section is arguing that the trading arrangements, like the physical infrastructure, the industry structure and the institutions that make up the electricity system, are structured in such a way that the existing centralised configuration is maintained. For this reason small-scale RE requires policy support that compensates for the difficulties that small generators have with selling their power.

SECTION 2.7 INVESTMENT IN ELECTRICITY GENERATION

This section explains how investment in electricity technologies is typically undertaken and it provides some background information on the main sources of capital and the role that risk has in investment decisions. It then shows how electricity investment tends to favour large-scale and incumbent technologies and that the risk associated with RE investment, and particularly small-scale RE investment, typically becomes more acute as the project size decreases. The section argues that accessing finance is a key barrier to developing small-scale RE projects and that without policy support that lowers the risk profile these technologies would not be deployed.

There are two distinct types of capital that can be sourced for financing an electricity project and each project will have a different balance between the two -

1. Debt – The loan of a fixed amount of money for a fixed period of time. It normally includes interest which is calculated as a percentage of the loan amount. Lenders, often banks, will focus on the ability of a project or borrower to pay back the loan and the loan terms will be based on this calculation. Debt is generally sought on lower risk projects and is a lower cost of capital than equity.
2. Equity – Stock or security representing interest or ownership in a project. Equity investors expect a return on their investment which they will calculate according to the perceived risk of the project. The risk-adjusted return will set the terms of the investment. Equity will be sought in higher risk projects and therefore requires a higher return than debt (Gross et al. 2010; Hamilton, 2006).

As the risk associated with an electricity project increases, so does the risk premium that will be attached to the investment. Generally, the higher the risk associated with a project, the higher the ratio of equity to debt (Glendale Power, 2009).

There are many potential risks relating to energy projects in general as well as a number of risks that are unique or particularly acute for RE projects. Each of these has an impact on the risk profile of a project and consequently the cost of capital. Table 2.1 details some of these risks.

TABLE 2.1 PROJECT RISKS AFFECTING ENERGY INVESTMENT

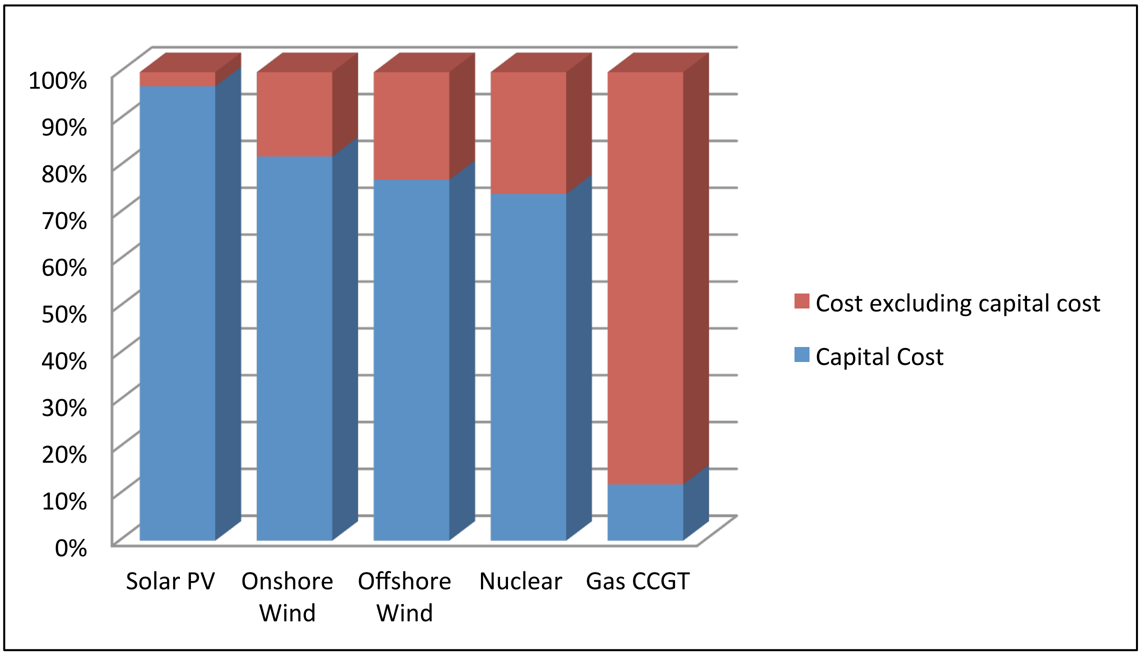
General Energy Project Risks		
Economic Risk	Market Risk	• Inadequate price and/or demand to cover investment and production costs • Increase in input costs
	Construction Risk	• Cost overruns • Project completion delays
	Operation Risk	• Insufficient resource/reserves • Unsatisfactory plant performance • Cost of environmental degradation
	Macroeconomic Risk	• Abrupt depreciation or appreciation of exchange rates • Changes in inflation and interest rates • Lack of appetite for lending or investment caused by wider economic trends/shocks
Political Risk	Regulatory risk	• Changes in price controls • Changes to environmental obligations • Cumbersome administrative procedures
	Expropriation/nationalisation risk	• Changing title of ownership of energy assets to the state or monopoly
Legal risk	Documentation/contract risk	• Terms and validity of contracts, such as purchase/supply, credit facilities, lending agreements and security/collateral agreements
***Force majeure* risk**		• Natural disaster • Civil unrest/war • Strikes
RE Project-specific Risks		
Offtake risk		• Finding a buyer or market for unusual clip-sizes • Intermittent generation profile
Planning		• Permission subject to local councils, area planning committees, and public opinion
Grid connection		• Long lead times for connection can delay operation • Connection can be expensive if upgrades to network are required

Source: Adapted from IEA (2003) and Ernst and Young (2012)

This multitude of risks present a considerable challenge for developing RE projects and investors and lenders will seek reassurances from potential developers that the risks will be addressed or mitigated. As Hamilton (2006) explains, in general experienced, established market actors who can spread project risk across a portfolio of investments and assets will be favoured over new, independent market entrants. As long as new market entrants are perceived to be a higher risk investment their cost of capital will remain relatively high. This makes the already marginal investment in smaller scale, renewable, or independently developed projects even more challenging to finance (Sauter and Bauknecht, 2009).

In addition to the risks and challenges associated with investment detailed above, electricity projects are typically more capital intensive than investments in other industries. This means that they have a high proportion of upfront fixed costs within their total lifetime costs. The more capital intensive a technology, the more money is committed at an early stage (relative to the capacity of the technology). This can leave an investor more exposed to macro-economic shocks or any risk that the project will fail (CCC, 2011a). This raises the risk profile of an investment and ultimately results in a higher cost of capital for the project. This investment characteristic is particularly acute for renewable projects and, as can be seen in Figure 2.3, generating technologies associated with smaller-scale schemes have the highest capital intensity.

FIGURE 2.2 SHARE OF CAPITAL COSTS IN LONG-RUN MARGINAL COSTS FOR GENERATION TECHNOLOGIES



Source: Adapted from CCC (2011b)

Another key barrier to financing small-scale schemes stems from the size of the projects themselves. Smaller schemes are inherently more financially marginal because there are a number of fixed costs and overheads involved in developing and operating any renewable plant such as grid connection, planning applications, market participation and regulatory compliance (Gross et al., 2010). The smaller the site the greater the burden of these fixed costs and therefore the smaller the potential returns available.

Thus there are a number of trends within electricity finance that create difficulties for projects with the investment characteristics of a small-scale RE scheme. In general the costs of financing a scheme, and the potential to raise funds at all, are far more challenging for small-scale RE than large-scale renewables and conventional generation. As with the other elements of the electricity system discussed in this chapter, investment practices favour incumbent and large-scale technologies to the degree that alternative options are locked-out without policy support. But this thesis argues that small-scale RE has a number of benefits that could have an important role in electricity system transition and it therefore focuses on the FIT as a policy designed to overcome these barriers.

SECTION 2.8 CHAPTER SUMMARY

This chapter has provided an overview of the electricity system in the UK and it has argued that each of the elements discussed is effectively a barrier to the development of small-scale RE. The physical infrastructure is dominated by large-scale thermal and nuclear generating plant and the system has developed around the characteristics that they demonstrate. Small-scale RE technologies have a number of benefits that have not been realised because they are an alternative to the dominant design. But the chapter argues that policy support is required to overcome the lock-in of a large-scale configuration. The industry structure, the institutional framework, the market design and the conventional financing practices have all developed around the large-scale physical infrastructure and it is argued here that they ultimately maintain this configuration. This serves to lock-out small-scale RE which is why policy is required to compensate for the disincentive to develop alternative projects and overcome the inertia in the system. The FIT has been introduced to provide this support and this research focuses on the role that the scheme has had in the electricity system as it attempts to decarbonise.

The following chapter explores the academic literature concerning theoretical and historical approaches to achieving transitions within large established socio-technical systems like electricity systems. It develops an analytical framework from this literature that will be used in this study to analyse the significance of the GB FIT in working towards a transition to a sustainable electricity system in the UK.

Chapter 3 – Theories of Electricity System Transition

SECTION 3.1 CHAPTER INTRODUCTION

The previous chapter outlined the various elements of the UK electricity system and argued that they have locked the system in to a large-scale configuration. This chapter explores the theoretical approaches to overcoming such barriers. There is an active academic literature which seeks to address the complex dynamics of system change, focused on transitions in socio-technical systems. This field offers an analytical perspective on the interactions between multiple system components and change. This chapter explores that literature and uses some of the indicators of transition to develop an analytical framework that will be applied to evaluate this research. That framework is introduced here but it is fully explained in Chapter 4 and then employed in chapter 7 and 8. It contributes to recent conceptual developments within the transition literature that operationalise the theory to assess existing policies aimed at stimulating transition.

There is a growing body of research concerned with the processes of innovation and socio-technical change in response to the challenges of climate change and sustainable development. Implicit in this work is the requirement to make a transition away from existing means of realising societal functions towards more sustainable systems. Transition scholars have tried to explain how this change might occur under different terms such as regime transformation (Van de Poel, 2003), technological revolutions (Perez, 2002), technological transitions (Geels, 2002), system innovation (Elzen et al., 2004; Geels, 2005) and transition management (Rotmans et al., 2001). These are collectively referred to in this thesis as transition theory.

Transition theory uses the socio-technical system as a framework, a term that recognises the many interrelating factors surrounding and influencing technological systems. A socio-technical focus aligns the processes of societal and technical change, suggesting that they both co-evolve and must be considered together. This co-evolutionary systems approach has in part developed out of Thomas Hughes's study of the emergence of electrical power systems (Hughes, 1983). He suggested that societal and technological patterns both cause and are influenced by wider economic, political and organisational change and must be understood as such. The concept of a *socio-technical system* thus captures this whole-system view and implies that any change within those systems will be a co-evolution of society and technology (Geels, 2004; Markusson et al. 2012).

SECTION 3.2 SOCIO-TECHNICAL SYSTEM TRANSITION

As Foxon (2011) explains, academic work around transition theory has developed along three main strands.

The first strand is a number of historical analyses of technological change, such as the transition from sailing ships to steam ships (Geels, 2002), systemic changes in the Dutch electricity system (Verbong and Geels, 2007), from horse-drawn carriages to automobiles (Geels, 2005a), biogas development in Denmark (Geels and Raven, 2006), from propeller aircraft to turbojets and from the use of surface water to piped water and sewerage systems (Geels, 2005 & 2005b). These analyses have been used to identify and illustrate the conditions that allowed previous transitions to occur. Emerging from this literature is an analytical lens developed by Frank Geels and colleagues (Geels 2002; Elzen et al. 2004; Rip and Kemp, 1998). The multi-level perspective (MLP) uses insights from evolutionary economics, sociology of technology, history of technology and innovation studies to organise analysis of socio-technical systems into a nested hierarchy of niches, regimes and landscapes (Geels and Schot, 2007; Geels, 2005). The historical analyses have provided a strong empirical, analytical core for the theory and much of the academic debate surrounding the MLP and transition theory is based on these studies.

The second strand has used transition as a basis for developing a process of governance called Transition Management. Initially developed for the Netherlands Fourth National Environmental Policy Plan (NEPPA), it starts from the insight that broad system innovation is required to address the systemic faults in society (Geels and Schot, 2007; Meadowcroft, 2005). In directly addressing this issue, it explores the roles of different actors within the process and suggests that a transition is non-linear with multiple causality. It seeks to deliberately steer the complex dynamics of transition through interactive, iterative processes between stakeholders. It is thus a participatory policy-making process built on systems thinking. The process involves creating shared visions and goals, mobilising change through transition experiments (niche innovations), and learning and evaluation of the success, or otherwise, of those experiments (Foxon, 2011).

The third main strand of transitions research uses the MLP to develop and structure socio-technical scenarios. These explore potential future configurations within socio-technical systems, the possible pathways towards those configurations and their implications (e.g. Elzen et al. 2004; Hoffman et al. 2004; Foxon et al. 2010).

The purpose of this research and thesis is not to continue work within these three strands but to build upon the analytical and theoretical platform that they all provide through operationalising the MLP theory. An analytical framework is used which draws on the literature in these three streams. The basis for that framework is the focus of the following sections, the first of which gives an overview of the MLP framework.

SECTION 3.3 THE MULTI-LEVEL PERSPECTIVE

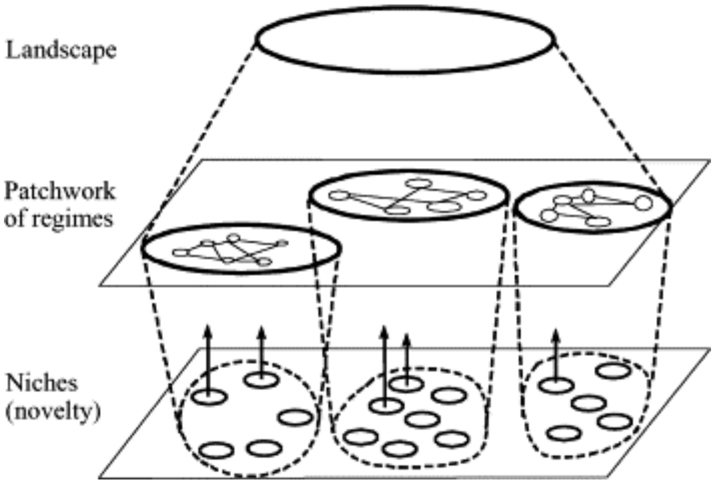
The socio-technical regime is a concept that has developed out of Nelson and Winter’s (1982) initial attempts to theorise the “technological trajectories” along which an engineering community centres, which in time limits the opportunities of alternative technologies. The regime constitutes a dominant, institutionalised, incumbent means of realising societal functions. It is structured by a specific set of unifying policies, technologies, institutions, practices and behaviours that stabilise the existing means and frustrate the capacity for alternatives to develop (Kemp et al. 1998; Geels, 2002; Shackley and Green, 2007). Regimes are discussed in more detail in Section 3.6.

Change within a regime typically occurs within established innovation patterns and is ultimately incremental and path dependant (Geels, 2002). More revolutionary and disruptive innovation occurs within niches which act as ‘incubation rooms’ for novel technologies, configurations and practices. Initially unstable and low performance novelties are carried by small networks of dedicated actors and developed until they are ready to challenge the regime (Smith et al. 2005; Rip and Kemp, 1998; Kemp et al. 1998; Geels and

Schot, 2007). A transition is a change from one socio-technical regime to another, often driven by the disruptive influence of niche developments. Niches are discussed further in Sections 3.4 and 3.5.

The MLP suggests that both niches and regimes are situated within a macro-level landscape which provides a structuring context for the whole socio-technical system. The landscape is the web of cultural and political values and deeply rooted economic trends that shape the system over the long term. The landscape offers both gradients (limits) and affordances (opportunities) for change within regimes and niches (Geels and Schot, 2007; Shackley and Green, 2007). Landscapes are discussed in more detail in Section 3.7. A very basic, but clear, schematic of the MLP is shown below in Figure 3.1.

FIGURE 3.1 THE MULTI-LEVEL PERSPECTIVE



Source: Geels (2002)

The MLP provides a useful lens onto system-wide change and it has synthesised many different strands of research into a unifying theory. It has received a great deal of attention, interest, and criticism within the academic literature, explored below, which has served to significantly move forward the way socio-technical systems are understood. Perhaps most usefully, it provides a heuristic for exploring the processes of innovation and for focusing whole system thinking in relation to societal functions (Rip and Kemp, 1998 and Geels, 2002). However, as this chapter will show, there are still opportunities for further research within the field of transition and in particular for operationalising the MLP in the evaluation of policy.

SECTION 3.4 NICHE

The MLP places great emphasis on the role of niches where the selection pressures that exist within the regime are less evident. It is argued that niches provide an isolated, pre-competitive environment where technologies, and the infrastructure and practices that support them, can develop relatively freely. The ‘protective space’ afforded by the niche allows initially unstable alternatives to improve their performance such that they might challenge the incumbent configuration within the regime (Geels and Schot, 2007; Smith et al. 2010; Rip, 1992; Kemp et al. 1998). Innovations within the niche are generally developed by small networks of dedicated actors who allow for the lower performance and the inconvenience of using a novel technology due to a belief in the potential social and environmental benefits.

Niche innovations are effectively real-life experiments which may fail or may develop to compete within the regime. Raven (2010) suggests that the protective space that allows them to develop can be afforded through a number of different means; shown in Table 3.1 below.

TABLE 3.1 CLASSIFICATIONS OF PROTECTIVE SPACE

Economic protection	**Subsidies, grants etc. E.g. a feed-in tariff for renewable electricity**
Institutional protection	Alterations to norms and rules e.g. suspending standard rules for grid connection
Socio-cognitive protection	Supporting new knowledge production e.g. through research councils
Political protection	Technologies become a part of a political agenda e.g. low-carbon economy
Geographical protection	Certain locations provide specific resources e.g. wave-hub in Cornwall

Source: Raven (2010)

Protection is often multi-dimensional involving a number of these factors together. Historical analyses of system transitions (e.g. Geels 2005a) have shown that niche innovations use this protection to ultimately branch out and link up with wider processes of change within the socio-technical system as a whole. In other words, niche pioneers have to align their expectations with the currents of change within the regime, as influenced by the landscape. The potential of the innovation will be constrained and interpreted by the more powerful actors and structures within the prevailing regime. This implies a degree of disruption for both niche and regime actors but ultimately the niche innovation outperforms a regime technology and either alters the configuration or takes over (Roep et al. 2003; Grin et al., 2004; Smith et al. 2010).

SECTION 3.5 THE ADVANCEMENT OF A NICHE INTO A REGIME

Within the MLP literature, and borrowing from academic work on strategic niche management, scholars have explored the necessary steps for the successful advancement of a niche innovation. Geels and Schot (2007) suggest that an innovation must build up its own internal momentum so that it is able to take advantage of any opportunity to break into the regime. There is a question of timing implicit in this process, whereby the development of a niche-innovation must coincide with an opening at the regime level. If the niche-innovation is not ready to advance into mainstream markets the opening may be lost. They suggest a number of indicators that demonstrate that a niche is sufficiently stabilised to be able to advance.

1. A technology must begin to show a clear trend of cost reduction and performance improvement away from the start-up and research and development stage before it can start to compete with the dominant configuration within the regime.
2. This must correspond with a demonstration of the learning effects discussed by Arthur (1994). This is the development of specialised skills and knowledge that can only accumulate through experience and increased production (Geels and Schot, 2007; Shackley and Green, 2007; Kern, 2012). This can lead to improvements in a technology and/or cost reductions. This concept has developed from Arrow's (1962) 'learning-by-doing' observations and further explored in learning curve research where the timings and costs of technology development are investigated (Foxon, 2002 & 2010).
3. Another central step is the support of powerful actors. As discussed above, niches are often able to develop with the backing of a dedicated network of actors, such as the role of environmental activists and hobby engineers in the early stages of wind energy (Klaasen et al. 2005). However, for a niche such as wind energy to challenge the regime and to have widespread influence, powerful regime actors such as the large energy utilities must begin to support the technology. These actors are able to provide financial investment, technical development, and scale benefits but they can also increase the social legitimacy of a technology by institutionalising its value (Smith et al. 2010; Schot, 1998; Späth and Rohracher, 2010).

In addition to these indicators, Raven (2006) and Smith (2007) argue that there is a critical role for niche actors who must persuade a variety of different regime actors (such as investors) of the potential of the technology. Raven and Smith suggest that niche actors must perform institutional, economic and political work in pushing the niche-innovation into the regime. However, this is likely to be challenging as incumbent actors may resist latent competitors by throwing up barriers to the novelty, by improving performance of the regime or by absorbing and diluting elements of the novelty to strengthen their own position (Elzen et al. 2004).

So for successful niche advancement a combination of requirements must develop. Cost and performance improvements, development in learning effects, and support from powerful actors. These requirements will be developed into the analytical framework for this study (illustrated in Figure 3.3 and explained in Chapter 4). The networking requirement discussed by Raven (2006) and Smith (2007) is also built into the analytical framework but it is combined with a regime process related to social networks. The following section details the characteristics of the regime and explores the steps and indicators required at that level for transition.

SECTION 3.6 REGIME

The socio-technical regime is the set of established, dominant technologies that are embedded within a social, political and institutional context that defines and maintains a set of rules, procedures, habits and practices. These interrelating factors stabilise existing configurations but have also been shown to lock a system in to an incumbent regime (Unruh, 2000; Unruh 2002; Geels, 2002; Shackley and Green, 2007).

Geels and Schot (2007) review the conceptual development of the regime starting with Nelson and Winter’s (1982) initial work in exploring the cognitive routines that materialise within engineering communities around ‘technological trajectories’. Hughes’s (1983) theory of the co-evolution of societal and technological change broadened the understanding of development in the regime. This was further extended by sociologists of technology to consider the additional actors that cluster around a dominant pattern of technological development such as policy makers, users and scientists whose work maintains its dominance (Bijker, 1995). The *socio-technical* regime encompasses this broader conceptualisation.

The way in which socio-technical regime stabilisation is understood has developed from a recognition of the cognitive routines of engineers to include the regulations and standards surrounding and supporting technological systems (Unruh, 2000 & 2002), the social adaptation of user lifestyles to incumbent regimes, and sunk investments in existing assets and competencies (Tushman and Anderson, 1986; Christensen, 1997; Geels and Schot, 2007). Verbong and Geels (2007) suggest that the regime has three interlinked dimensions that maintain its stability:

1. A stable network of actors and social groups – e.g. In an electricity regime this would include utilities, Government departments, large industrial users and households etc.
2. Formal, normative and cognitive rules. Formal rules include regulations, standards and laws. Normative rules include role relationships and behavioural norms. Cognitive rules include belief systems, problem agendas, and guiding principles.
3. Technological elements – e.g. For the electricity regime this would include resources, grid and generation plant.

(Verbong and Geels, 2007, p. 1026).

Due to the stability created by interdependencies between the different system dimensions, innovation within a regime will typically be incremental and path dependent. Niches must overcome and disrupt this stability if they are to challenge dominant configurations (Geels, 2002).

Despite the stability displayed within regimes, and the lock-in that this creates, there are windows of opportunity where niche-innovations can begin to compete with incumbent technologies. Smith et al. (2010) argue that this can derive from within the regime; a point they feel has been undervalued in the MLP. Berkhout et al. (2004) also argue that the MLP tends '*to emphasise processes of regime change which begin within niches and work up, at the expense of those which directly address the various dimensions of the socio-technical regime or those which operate "downwards" from general features of the socio-technical landscape*' (p.62). Incumbent firm research and development, or changes in Government regulations can create misalignments such that alternatives are sought. But an opening in a regime is also seen to be a response to changes at the landscape level, or interaction with other regimes, which can challenge the efficacy of regime configurations (Raven and

Verbong, 2007 and Konrad et al., 2008; Geels and Schot, 2007; Smith et al. 2010; Smith et al 2005). An example is climate change which has been created by the unsustainable characteristics of a number of regimes (e.g. electricity, road transport, food production) over the long term, but which is now destabilising the appropriateness of those causal regimes (Scrase and MacKerron, 2009).

The electricity regime in the UK has a stability and inertia created by the system elements that were discussed in Chapter 2. As that chapter argued, the incumbent physical infrastructure, the concentrated market structure and ownership, the market-based institutional framework and network regulation, the market design and trading arrangements, and the investment trends and preferences all maintain a configuration centred on large-scale technologies. This thesis argues that overcoming this inertia is a significant barrier to electricity system transition and also the deployment of small-scale RE. Therefore, evaluating the role of the FIT in system transition requires analysis of the impacts that the scheme is having on the regime, and the developments within the regime that are impacting on the FIT. Verbong and Geels (2007) suggest that breaking lock-in within a regime such as this would require a change within the three interlinked dimensions that maintain its stability, as discussed above. These are the network of actors and social groups, the existing rules of the regime, and the technical/physical elements. These three dimensions will be built into the analytical framework which is illustrated in Figure 3.3. The following section explores the landscape level of the MLP.

SECTION 3.7 LANDSCAPE

The landscape is the macro-level context that structures the socio-technical system. It includes the prevailing macro-economics, deep cultural patterns, and macro-political developments that shape society. Change at the landscape level is generally quite slow, and it does not directly determine what happens at the lower levels. Rather it creates *gradients of force* or *affordances* which can act to either constrain or allow change from a high level (Geels, 2005; Verbong and Geels, 2007). Examples of landscape processes include '*environmental and demographic change, new social movements, shifts in general political* *ideology, broad economic restructuring, emerging scientific paradigms, and cultural developments'* (Smith et al. 2010, p. 441). As these processes develop pressure can build for change at the regime level, destabilising the existing configuration and creating opportunities for niche-innovations to break through.

Landscape developments affecting the electricity regime include climate change, neo-liberal economic ideology, resource shocks such as the 1973 oil crisis[13], and energy security concerns stemming from unstable resource availability. Factors such as these can question the efficacy of existing regime configurations to meet the needs of society which can destabilise incumbent technologies, actors and practices. This can also create new value for alternative characteristics such as low-carbon generation or generation fuelled by domestic resources which could outperform existing technologies within the new context (Shackley and Green, 2007).

This thesis evaluates the role that the FIT is having in electricity system transition in the UK. Developments at the landscape level can have a very significant impact on how a transition develops through creating opportunities and constraints for the rest of the system. It is therefore necessary in this thesis to analyse the landscape as it relates to the FIT and the electricity system, as this will have consequences for the role of the scheme and for small-scale RE. Kern (2012) and Geels and Schot (2007) suggest that macro-political, socio-cultural and macro-economic developments are the central drivers of change, or stability, at the landscape level and these are therefore built into the analytical framework, illustrated in Figure 3.3. These are analysed for their causal significance in relation to the FIT. In other words, the analysis identifies the processes occurring at a landscape level that are impacting on the FIT and not the other way round. The FIT has only been in place for two and half years but landscape processes are inherently slow moving (e.g. climate change). It is unrealistic to evaluate the impact that the FIT has had on the landscape because it is such a

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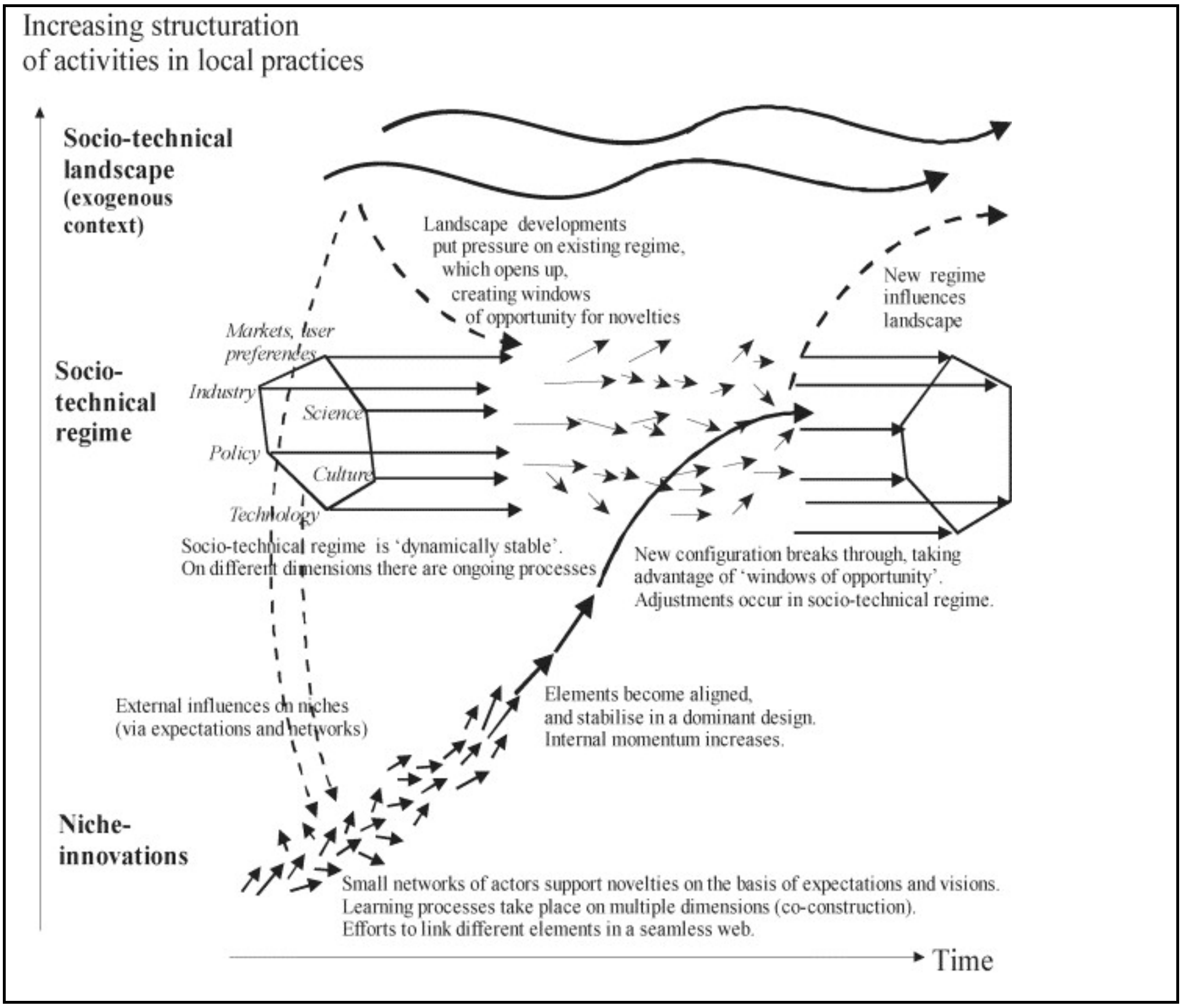
[13] The 1973 oil crisis was the result of an embargo by the members of the Organization of Arab Petroleum Exporting Countries, which was the Arab members of OPEC, plus Egypt, Syria and Tunisia. The embargo was a response to the U.S. role in the Yom Kippur war and it resulted in the oil price quadrupling and remaining high until an oil price crash in 1986.

recent development in the electricity system in the UK. The following section outlines the process of transition itself, as debated within the MLP literature.

SECTION 3.8 THE TRANSITION PROCESS

The MLP theory is constantly being developed in response to its application and criticism (discussed in Section 3.9) but the basic concept posits that transitions occur through interactions between the three levels of niche, regime and landscape. As discussed above, niche-innovations must first build up an internal momentum through price-performance improvements, through continued learning processes, and increasing support from powerful groups. Landscape processes such as environmental change create pressure on regimes and from a high level, shift the normative drivers of regime configuration. This destabilises the incumbent regime which then creates an opportunity for niche-innovations to break through into mainstream markets, and to ultimately establish a new regime. The new regime will, in time, then influence the landscape and the process will continue. This is illustrated in Geels and Schot's (2007) schematic below.

FIGURE 3.2 TRANSITION IN THE MLP



Source: Geels and Schot (2007)

Geels and Schot (2007) refined this illustrative process in response to some of the criticisms discussed in the next section. They introduced a typology of five potential transition pathways that varied by the timings of interactions between the three MLP levels, and the nature of those interactions. These typologies are introduced below.

1. Reproduction process: Incremental processes of change within the socio-technical regime that are not driven by interaction with the landscape or technological niche. This is business-as-usual for the regime with steady improvements in existing practices.

2. Transformation path: Landscape developments place pressure on the regime to

change. The niche level is too undeveloped to provide solutions and there is therefore a reorientation of activity within the regime by incumbent actors.

3. De-alignment and re-alignment path: Divergent, significant change at the landscape level leads to de-alignment and erosion of the regime. A number of niche-innovations compete and eventually one emerges as the new dominant option.

4. Substitution: Significant landscape pressure erodes the regime but the niche is sufficiently developed to replace it and become the new dominant configuration.

5. Re-configuration pathway: Niche-innovations are adopted into the regime to solve specific issues but they trigger larger adjustments and ultimately reconfigure the regime (Geels and Schot, 2007; Shackley and Green, 2007).

As Geels and Schot (2007) indicate, these pathways are a refinement of the general theory of transition. They offer five alternative options for how change can occur in socio-technical systems, and what the interaction could be between the three system levels, and across time. But system transitions are complex processes that involve multiple factors and it is challenging to try to abstract those factors such that a transition can be classified. However, it is useful when evaluating a system that is changing to be able to analyse what is happening at a whole-system level. Socio-technical systems are highly complex and there are many interacting processes that occur, as this chapter has indicated. In the case of the electricity system, this thesis argues that a transition is occurring, largely in response to the legal targets for emissions reduction and RE.

SECTION 3.9 CRITICISM OF THE MLP

The MLP provides a useful lens for systems based analysis and it has stimulated some progressive work around transitions to sustainability. This thesis suggests that in relation to energy studies, it has provided scholars with a structure with which to break down the many interrelated processes and developments occurring within an energy system, creating a degree of continuity in analyses and significantly moving forwards understanding of system dynamics. The MLP, and socio-technical systems more generally, have received much attention within the academic literature and there is a growing body of academic work. The theory has been challenged and refined many times. This section does not review all of these critiques but explains some of the criticisms that are relevant to this research.

One of the central criticisms of the socio-technical system, and MLP, approach is that by providing a structure that encompasses not only an established system, but also the innovatory periphery where alternatives are created and the overarching context that influences the whole system, there is a danger of trying to cover too many factors. This could result in an over-abstraction of the complex processes occurring such that important detail is lost (Smith et al. 2010). It is a useful contribution of theoretical work to analyse multiple interactions and draw conclusions about the implications on a system level but there is a balance to be found between illuminating a wider impact, and over-simplifying a complex process. This will be considered throughout the analysis conducted in this thesis.

Geels (2011) considers seven criticisms that have been published in relation to the MLP. These include -

1. A lack of agency;
2. Operationalisation of regimes;
3. Bias towards bottom-up change models;
4. Epistemology and explanatory style;
5. Methodology;
6. Socio-technical landscape as residual category; and
7. Flat ontologies versus hierarchical levels.

These seven criticisms will each be briefly discussed below as they represent the most significant refinements and defence of the MLP since it was first developed (Geels, 2002).

SECTION 3.9.1 A LACK OF AGENCY

Smith et al. criticised the MLP for being *'too descriptive and structural, leaving room for greater analysis of agency'* (2005, pp.1492). Genus and Coles also argue that there is a need within the MLP to *'show concern for actors and alternative representations that could otherwise remain silent'* (2008, pp.1441). Both papers claim that there is insufficient development within the MLP to explain or analyse the agency of different actors within the process of transition. Agency in this context is defined as the ability to take action and make a difference over a course of events (Giddens, 1984; Smith et al. 2005).

As the discussion above points out, there is a danger when theorising complex processes such as a system transition that important aspects of those processes are not adequately contained – that so many aspects need to be addressed that it is not possible to include them all. The role of various actors within transition and the agency prospective actors do, or do not, have is a critical element in understanding how change occurs and should therefore be central in any theory of change (Geels, 2004; Markusson et al. 2012; Hughes, 1983).

Geels (2011) counters these criticisms by arguing that although agency is not explicitly shown within the explanatory MLP diagrams (Figure 3.1 and Figure 3.2) it is an intrinsic element of MLP theory. He explains that the arrows within Figure 3.2 represent trajectories that are enacted by social groups who implicitly have agency within the process. He also indicates that the underpinnings of the MLP lie in a crossover between evolutionary economics and Science and Technology Studies (STS), both of which consider agency – evolutionary economics includes materialist aspects such as prices, capital stocks, investments, resources, competition, market selection; STS includes idealist aspects such as interpretations, visions, beliefs, networks, and debate (Geels, 2011). Geels argues that this underpinning ensures that agency is *'shot through'* the MLP. However he does concede that some aspects of agency could be further developed by including insights from other theories including political science theories on the role of power, social movement theory, cultural sociology, discourse theory, business studies, and strategic management.

Geels argues that the MLP is a middle range theory that sits between all-inclusive unified theories of abstract entities such as society and everyday hypotheses that are developed through empirical research (2011). Therefore the MLP uses empirical research to identify patterns but it attempts to relate these to various wider concepts taken from other theoretical work. Agency is one such concept that Geels argues is underpinning the MLP, but that further work can be done to draw this out, using other theories (Geels, 2011). This leaves space for constant theoretical development of the MLP.

SECTION 3.9.2 OPERATIONALISATION AND SPECIFICATION OF REGIMES

The regime concept within the MLP has been criticised for a lack of clarity that hinders its operationalisation in empirical research. Berkhout et al. (2004) claim that '*it is unclear how these conceptual levels should be applied empirically. By this we mean that a sociotechnical regime could be defined at one of several empirical levels'* (p.54). This has implications for the conclusions from empirical research because if an electricity regime can be defined at different levels (e.g. primary fuel [coal, gas etc.] or entire system [production, distribution and consumption of electricity]) different results on the process of transition could be found. A regime shift at one level (e.g. phase-out of coal) may only be an incremental change at the wider level (e.g. if gas and nuclear power become the new centrepiece of a centralised system). Geels (2011) dismisses these criticisms and suggests that they concern a common problem of boundarising empirical studies. He suggests that the researcher must clearly demarcate the object of analysis so that conclusions cannot be misinterpreted.

However, there is a further criticism of the regime concept that it is sometimes employed as short-hand for “rules” and sometimes for “system”. These uses indicate alternative interpretations of the concept of a regime which leads Markard and Truffer (2008) to call for greater '*conceptual rigour in the identification and delineation of a regime*' (p.606). Geels responds by making a distinction between “system” and “regime”. A system is the tangible and measurable elements such as artefacts, infrastructure and regulation. A regime refers to the intangible and underlying deep structures such as engineering beliefs, routines and standards. Geels states that '*”regime” is an interpretive analytical concept that invites the analyst to investigate what lies underneath the activities of actors who reproduce system elements'* (2011, pp.31).

One further criticism of the regime concept is that they are often presented as a homogeneous, monolithic entity rather than a contested space involving tensions and conflicts of interest (Smith et al. 2005). Geels (2011) responds by acknowledging that variety exists within regimes but that there remains a coherence in many instances. He suggests that the internal alignment of regimes should be an empirical question in studies employing the MLP rather than an assumption.

The responses to the criticism over the conceptualisation of "regime" provide a useful clarification. The theory is in constant development and many researchers are employing, critiquing and adapting the MLP framework. It is important that the terms and concepts are continually reassessed to reflect the development that is occurring.

SECTION 3.9.3 BIAS TOWARDS BOTTOM-UP CHANGE MODELS

Berkhout et al. (2004) argued that the MLP places too great an emphasis on the role of bottom-up niche innovations in driving transition. They suggest that this focus occurs '*at the expense of those which directly address the various dimensions of the sociotechnical regime or those which operate "downwards" from general features if the sociotechnical landscape'* (Berkhout, 2004, pp. 62).

Geels agrees that early work with the MLP focused on niche-driven change but then suggests that more recent developments have sought to build in alternative change models. Geels and Schot's (2007) typology of transition pathways describes five alternative models of change that vary by timing and nature of change (see Section 3.8). Geels (2011) also suggests that further work could be undertaken to adapt work from the literature on political revolutions that, although distinct from transition, has a number of similarities that warrant future research.

SECTION 3.9.4 HEURISTICS, EPISTEMOLOGY AND EXPLANATORY STYLE

Genus and Coles (2008) argue that the '*potential contribution of the MLP/transitions framework could be limited to offering a heuristic device that can be used to organise sets of historical data about long term, complex and competitive technological trajectories*' (p. 1442). By this they mean that the MLP provides a lens for analysing system-dynamics rather than an explanation. Different researchers employ the theory in different ways but Genus and Coles suggest that the MLP has limitations for actually explaining the co-evolution of society and technology.

Geels' response to this criticism is to argue that heuristic devices are important tools for effectively analysing systems and that this is therefore a strength of the MLP. He states that '*frameworks such as the MLP are not "truth machines" that automatically produce the right answers once the analyst has entered the data. Instead they are "heuristic devices" that guide the analyst's attention to relevant questions and problems. Their appropriate application requires both substantive knowledge of the empirical domain and theoretical sensitivity (and interpretive creativity) that help the analyst "see" interesting patterns and mechanisms'* (Geels, 2011, p. 34). This is an important response for understanding the utility of the MLP and the analytical framework in this thesis attempts to build up from this interpretation. However, it is important to note that Geels is stressing the need for sensitivity in operationalising the framework – it cannot be unquestioningly applied to a topic but must be rooted in an extensive empirical understanding (2011). This thesis attempts to ensure that this is upheld in the analysis presented throughout.

SECTION 3.9.5 METHODOLOGY

The fifth criticism of the MLP that Geels (2011) addresses is again from Genus and Coles who argue that the historical case studies that are used to demonstrate the applicability of the MLP (e.g. Geels 2005; Geels, 2005c) are based on a '*flawed use of secondary data sources'* (2008, p. 1441). Geels (2011) acknowledges that transition case studies to date have focused on illustrating and exploring the MLP as a framework rather than a basis for systematic research. This has resulted in an underdeveloped discussion of the sources of data and the ways in which information has been interpreted. He calls for further empirical work employing the MLP; the design of this research is in part a response to that call.

Geels also discusses the issue of over-reliance on an individual case-study to draw conclusions on transition. He concedes that methods that bring in comparative analysis across different cases and times could add to the methodological credibility of the MLP. However, he also argues that research into complex processes of transition requires ‘creative interpretation’ on the part of the researcher and methodology should not limit this flexibility (Geels, 2011).

SECTION 3.9.6 SOCIO-TECHNICAL LANDSCAPE AS RESIDUAL CATEGORY

Geels discusses the criticism of the socio-technical landscape as a residual category, or a concept that accounts for too many types of contextual influences (2011). He states that early work around the MLP conceptualised the landscape as stable or slow-moving factors such as soil conditions. Later developments introduced a more differentiated understanding with three types of landscape dynamic –

1. Factors that do not change or that change very slowly such as climate;
2. Rapid external shocks such as wars;
3. Long term trends such as demographical changes (Van Driel and Schot, 2005; Geels, 2011, p. 36).

Geels suggests that this development could be continued with a further theorisation of the landscape concept.

SECTION 3.9.7 FLAT ONTOLOGIES VERSUS HIERARCHICAL LEVELS

The last criticism addressed by Geels relates to the hierarchical nature of the MLP. Early versions of the framework (see Figure 3.1) presented a clearly hierarchical view of system change in which small niches attempted to enter the larger, more stable regime which was in turn influenced by the overarching landscape. Geels argues that this early work has been developed and that now the different MLP levels more accurately refer to different levels of stability, and are not necessarily hierarchical.

However, Shove and Walker (2010) argue for a less hierarchical, more horizontal approach using social practice theory. This rejects the MLP and focuses on the adoption or rejection of sustainable practices. They look at the reproduction of practices and the impact this has on elements such as technology, meaning and skills. Geels responds by accepting that the "hierarchy" notion built into the MLP presents a misleading view of transition. He acknowledges that the more horizontal view, proposed by Shove and Walker (2010) that focuses on interrelating practices introduces a potentially fruitful alternative to the MLP. However, he argues that there is a complexity associated with practice theory that has not been as thoroughly developed as within transition theory and it is therefore not yet clear how operational this alternative could be for empirical research.

SECTION 3.9.8 CONCLUSIONS ON MLP CRITICISMS

The MLP is a well contested theory. It has sparked a development in the understanding and framing of transition and in the dynamics of large systems. There are critiques from many angles, some of which Geels has attempted to respond to, as reviewed above. His approach is to frame the criticisms as potential areas for further development.

The contribution of this thesis is not to attempt to engage in this theoretical development but rather to accept the view of Genus and Coles (2008) who suggest that the MLP provides a heuristic for analysing complex processes. The analytical framework employed in the thesis attempts to operationalise the insights gained from the development of the MLP. The criticisms discussed above have been central in driving this development and they are considered throughout the analysis presented below. However, the thesis operationalises the theory in order to test the validity and utility of the MLP for empirical analysis of policy as it relates to transition.

In addition, as discussed above, there is a criticism of the MLP that it provides an overly structural explanation for processes of change and that it does not address the roles and agency of actors contained within the system, or for the economic factors that influence how change occurs (Foxon, 2011; Smith et al. 2005). Nye et al. (2010) argue that '*practical perspectives on the more social aspects of socio-technical transitions remain somewhat undeveloped and perfunctory in nature' (p.698).* They focus their research on the roles of domestic actors in wider processes of transition but this thesis suggests that there is a further requirement to explore the social *interactions* between actors operating at different levels of a system and this thesis makes a contribution to the transition literature by directly addressing this gap.

The three main strands of work in transition theory, as stated above, are historical analyses, transition pathways and transition management. These strands have served to explore the application of the theory against past or future configurations, but much less work exists that applies the theory to evaluate current developments. Genus and Coles (2008) ask whether the MLP can be usefully applied to evaluate existing policy as it progresses. The following section explains how this research builds on work by Kern (2012) to address this gap in transition research by operationalising the theory.

SECTION 3.10 OPERATIONALISING THE MLP AND THE ANALYTICAL FRAMEWORK APPLIED IN THIS THESIS

This thesis adopts the MLP framework as a means of analysing an existing policy mechanism aimed at stimulating small-scale RE generation. It recognises the theoretical work within the transitions literature but its contribution is to *operationalise* that theory, and specifically the MLP. The indicators of internal momentum within a niche, the signs of destabilisation within a regime, and the broad developments at landscape level that put pressure on the socio-technical system, are all used as indicators of transition, built into an analytical framework that is applied to the small-scale FIT (see Figure 3.3). The analysis assumes that if these processes are necessary for a transition to occur, then a policy mechanism should stimulate or respond to those processes to be constructive in moving towards a transition. It therefore evaluates the degree to which the FIT mechanism is stimulating or responding to the processes necessary for transition, as proposed in the MLP literature. This is then developed to answer the central research question of this thesis; what is the role of the small-scale FIT in electricity system transition in the UK?

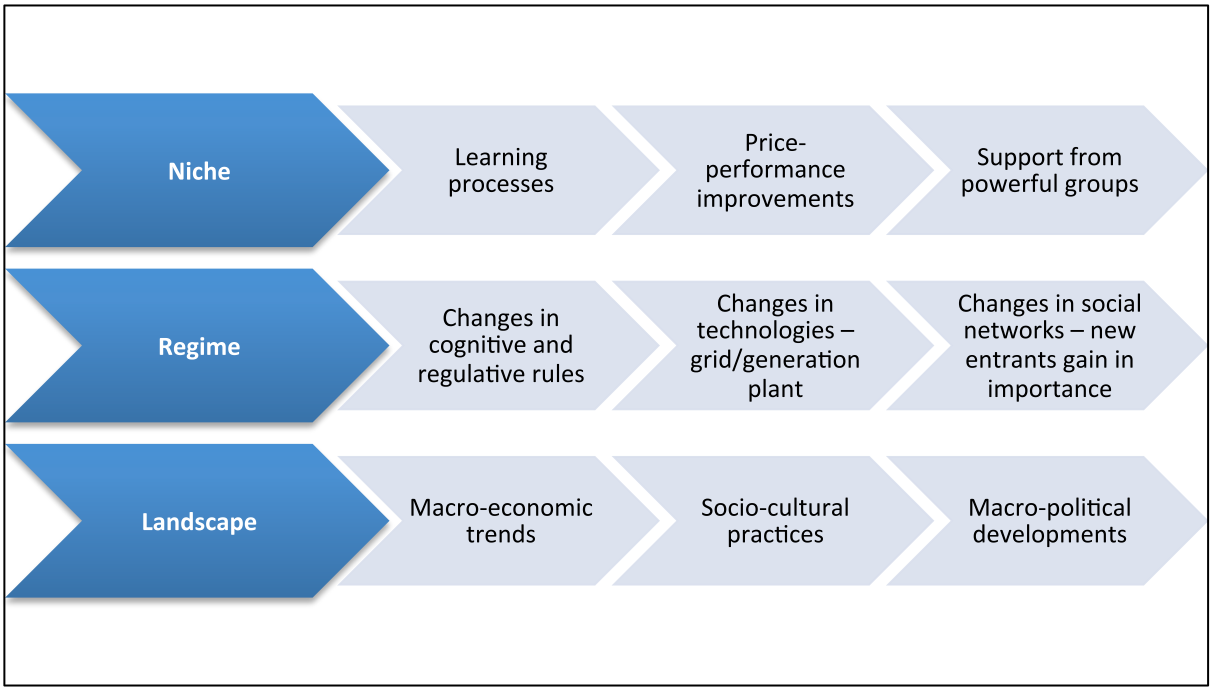
Haxeltine et al. (2008) and Smith et al. (2010) suggest that there is still considerable work to do in formalising the MLP into detailed methods for empirical research. It is argued that both qualitative and quantitative research into existing systems will always be '*partial, situated and temporary*', without the benefit of retrospect afforded by historical analyses (Smith et al. 2010, p. 445). However, this thesis argues that despite the analytical challenges of research into existing, complex, emergent systems, providing reflexive narrative accounts of these systems in flux could significantly contribute to academic understanding of system dynamics. The experience and actions of stakeholders in the process of transition is a critical aspect and a more detailed analysis of these practices could not only be used to feed back into transition theory, but also to inform real-world practice. This thesis therefore makes a contribution to research into transitions as well as an empirical contribution by analysing the FIT in depth.

The analytical framework used in this study builds on recent work by Florian Kern who, rather than employing the MLP as a framework to inform policy, uses it '*for the analysis* ***of*** *policy*' and to '*think about the potential of particular policy instruments to contribute to wider transition processes*' (Kern, 2012, p. 299/300). Kern develops a framework that draws on work on the MLP found in Geels and Schot (2007), Shackley and Green (2007), and Verbong and Geels (2007). Using the indicators that this review has highlighted, he evaluates the role and success of the Carbon Trust in stimulating a transition to a low-carbon economy in the UK.

The framework provides a structure for Kern's analysis of the Carbon Trust but also a measure of the impact the organisation has had (Kern, 2012). The analysis includes a tick-list of each transition indicator against the activities of the Carbon Trust. This is an interesting interpretation of the utility of the MLP because it takes a number of processes that transition scholars have found to be necessary for socio-technical system change to occur, and applies them as required policy outcomes. There is a danger in doing this that a policy mechanism is assessed against criteria that did not drive its design. However, what Kern does is to fill in the space between a high-level objective for the Carbon Trust of stimulating a transition to a low carbon economy, with a number of processes that are viewed, in the academic literature, to be necessary for achieving it. This moves on from a narrow analysis of decarbonisation policy such as cost per tonne of carbon saved, and attempts to build systems thinking into policy analysis.

Kern concludes that '*further detailed empirical analysis of other policy initiatives is required to complement the picture*' (2012, p. 308). This thesis answers this call with an analysis of the GB FIT for small-scale RE generation. It uses a similar framework, adapted from Kern's, to analyse a different policy mechanism in order to further the understanding of the usefulness of the MLP for policy analysis. The main contribution of the thesis is empirical, with an in-depth analysis of the efficacy of a policy mechanism but transition theory is applied through the framework to illuminate what impacts the FIT is having at a system level and how the system is influencing the policy. An illustration of the analytical framework to be employed is below but the way in which it will be applied to the empirical findings from this study is explained in Chapter 4. The rationale for adopting the framework and the ways in which it has been adapted are discussed in Section 3.11 below.

FIGURE 3.3 ANALYTICAL FRAMEWORK EMPLOYED IN THIS THESIS



Adapted from Kern (2012)

The processes included in each level of the analytical framework are described in Section 3.4 – 3.7 above.

In this research the niche level is split into individual technology-niches. Solar PV, wind, AD, and hydro are all defined as individual niches and each niche has characteristics that are unique to that one technology. The niche, as with the definition of innovation in this thesis, does not just relate to technical aspects and development but also the social, commercial, and financial aspects that are associated with the technology. For example, developments in the hydro niche could include progress in commercial practices or better understanding of how to finance hydro projects. Thus the niche is an encompassing term for the various elements relating to each FIT technology.

SECTION 3.11 RATIONALE FOR ADOPTING KERN'S FRAMEWORK AND ADAPTATIONS MADE

Kern's analytical framework was adopted and adapted for application in this thesis because it provides a coherent means of evaluating the role that a policy mechanism has in the process of transition. The theory of the MLP, and of transition, is still very much in development and the processes that the theory focuses on are contested (see Section 3.9). However, one of the key strengths of the theory is to draw on theoretical work in other areas such as strategic niche management, STS, and evolutionary economics. This increases the conceptual legitimacy but also underpins the processes that are put forward as indicators or necessary requirements of a transition. This underpinning is one of the justifications for employing the MLP to this research.

This thesis argues that Kern has undertaken an important step in the development of the MLP by formalising the processes occurring at each level and creating a structure that can be employed in different policy analyses. Part of the contribution this thesis makes is to further test and demonstrate the utility of the analytical framework for policy analysis. The strengths and weaknesses of the framework will be evaluated in Chapter 9 and it is hoped that this will contribute towards the development of the framework and the MLP.

The MLP and socio-technical transition theory have received a lot of academic attention in recent years but there are other theories and frameworks available for analysing change in large systems. One alternative framework that was considered for application in this thesis is the coevolutionary framework developed by Foxon (2011). The framework is designed to provide *'a useful and flexible framework for analysing topics of current theoretical and policy interest relating to a low carbon transition'* (Foxon, 2011. p. 2259). It builds on the work within socio-technical transition research by combining it with insights from coevolutionary approaches and ecological economics. Foxon (2011) proposes a framework that considers the coevolution of –

1. Ecosytems;
2. Technologies;
3. Institutions;
4. Business strategies; and
5. User practices.

These are analysed within a micro-meso-macro perspective – a perspective that broadly relates to the niche-regime-landscape concept within the MLP (Foxon, 2011). The framework implies that transitions to more sustainable systems occur through technological changes, forming of institutions, revisions to business strategies, changes in user practices, and a positive interaction of these changes with the natural ecosystem.

Although transition research discusses the coevolution of system elements and argues that this underpins the theory, Foxon's framework focuses on the interactions that drive this coevolution. It goes beyond identifying the important elements of a system and looks at the way they interact and change together. This is a very useful development of the theorising around transitions and it provides a coherent platform for analysing change. However, it was not selected as the framework in this thesis for two key reasons –

1. The five system elements identified by Foxon (ecosytems, technologies, business strategies, user practices, and institutions) are all very large areas of analysis in themselves. For example, analysing the business strategies that have been introduced by a policy mechanism such as the FIT represents a large amount of work in surveying the industry to find out the changes between strategies before and after the policy was introduced. To then explore in depth the impact that a policy has had on user practices and the way in which these two elements have coevolved is a very large research project. To undertake this for the five elements identified in Foxon's framework was considered to be too large a research project for the time and resources available. Exploring just one of these elements could constitute a 3-year study.
2. The second reason for employing the MLP, and the framework developed by Kern, is that socio-technical transition research is currently such a prominent area of academic research. The motivation for this research was to feed in to this rapidly developing and important area of work, and it is hoped that the research can have an impact as widely as possible. The framework will be evaluated in Chapter 9 to reflect on it's utility, and on the implications for MLP research, so that it is not just uncritically employed. It is important that alternative theories are developed to challenge the MLP and Foxon's work achieves this, but the theoretical contribution of this thesis is to demonstrate whether the MLP has utility as a policy evaluation tool and thus contribute to it's on-going development.

There are two main adaptations that have been made to the analytical framework that Kern (2012) employed in evaluating the Carbon Trust -

Adaptation 1: Kern included a niche process entitled "Establishing Market Niches". This process accounts for the level of market penetration of a niche technology and consequently the capacity for the adoption to become self-sustaining, at which point the innovation can break through into the regime. Geels and Schot (2007) included this process in a list of proxies that can act '*as reasonable indicators for the stabilisation of viable niche-innovations that are ready to break through more widely*' (p. 405). The other three proxies are included in the framework used in this thesis but the "Establishing Market Niches" indicator has not been included (see Figure 3.3). The reasons for this are explained below.

Geels and Schot (2007) suggest that an innovation must account for 5% of market share to meet the requirements of the "market niche" indicator. This is derived from diffusion research by Rogers (1996) who suggests that a diffusion curve will become self-sustaining between 5 and 20% of cumulative adoption. It is not made clear by Geels and Schot (2007), or by Kern (2012), what the boundaries of the "market" are. The market could be for RE at all scales, or all electricity generation capacity. This distinction is obviously critical in establishing the level of market penetration but it is not clarified.

The interpretation of this indicator that is employed in this thesis is that it is necessary to assess the degree to which the niche-technology has penetrated the whole electricity generation market. This assessment is undertaken at the regime level under the "Changes in technologies – grid/generation plant" indicator. These two indicators appear to be assessing the same process in this instance. The "market niche" indicator is therefore left out of the analytical framework in Figure 3.3 and it is not included in the analysis.

Adaptation 2: Kern includes four processes to be analysed at the landscape level – macro-economic trends, socio-economic trends, macro-political developments, and deep cultural patterns. However in the analysis (p.306) Kern combines the macro-economic and socio-economic trends into one short paragraph without making a clear distinction between the two. However, the analysis does provide a coherent and concise description of the ways in which economic issues at the landscape level have affected the work of the Carbon Trust and the research does not seem to lack a more distinct analysis of macro- and socio-economic factors.

In addition to this, Geels and Schot (2007) only include one economic indicator in their list of landscape processes that influence the regime and niche levels (along with deep cultural patterns and macro-political developments). Therefore, in order to focus the analysis and to provide a coherent economic evaluation only one economic indicator is included in the framework – macro-economic trends.

In addition, the "deep cultural patterns" indicator included in Kern's framework is widened in this thesis to explore "socio-cultural practices". This is done to ensure that social, as well as cultural, factors operating at a landscape level are included in the analysis. Shove and Walker (2010) argue that analysing how established practices are replaced, how new social practices become adopted, and how they stabilise can explain how change at different scales occurs. Also, Ropke (2009) argues that '*social patterns such as the division of labour, gender relations, and unequal access to resources, as well as political, economic, legal and cultural institutions are constituted by practices, but they also provide a context for the performance of practices that is necessary to include in empirical analyses'* (p. 2493). Socio-cultural practices are therefore included in the framework employed in this thesis.

SECTION 3.12 CHAPTER SUMMARY

This chapter has explored the theory of socio-technical system transitions, including the MLP, and it has explained how these will be applied to the analysis in this thesis. Each of the MLP levels was explained and the process of transition itself was discussed. Transition theory is contested and is constantly being applied and refined by researchers. Some of these criticisms were identified and have been built into this research. The analytical framework was then explained and illustrated.

The MLP has been chosen as a theoretical lens because it provides a useful structure with which to break down the many interrelated processes, developments and dynamics occurring within the electricity system around the FIT. In adapting Kern's framework this thesis is creating a degree of continuity in analyses and it presents a coherent attempt to operationalise the MLP. Transition scholars have argued that change occurs in a socio-technical system through the interaction of the niche, regime and landscape levels. The way in which this interaction develops is central to understanding wider system dynamics and the analysis in this thesis therefore focuses on each MLP level but also how they affect each other. In order to understand the role of a policy mechanism within transition it is helpful to define how the broader system is changing so that the impacts of the mechanism can be evaluated in context. The analytical framework developed in this chapter provides the structure to do this.

The next chapter outlines the methodology applied to this study and it explains how the empirical research was undertaken.

Chapter 4 - Methodology

SECTION 4.1 CHAPTER INTRODUCTION

This chapter outlines the methodology applied in this research and it describes the methods used in the primary data collection and data analysis. The study employs an interpretevist, qualitative approach that triangulates (a "*method of finding out where something is by getting a 'fix' on it from two or more places*" [Robson 2002, p.371]) information from three sources:

1. A set of 37 semi-structured face-to-face interviews with purposively selected participants (Section 4.4);
2. Attendance at industry and Government meetings and events (Section 4.5);
3. Document analysis of consultation responses, publications and statistics from Government and the energy regulator, Ofgem (Section 4.6).

The data that is generated from these three sources is analysed using the analytical framework discussed in the previous chapter. The way in which it is applied is explained in Section 4.7. The overall methodology was designed specifically to answer the research questions, below –

CENTRAL QUESTION

What is the role of the small-scale feed-in tariff in electricity system transition in the UK?

SECONDARY QUESTIONS

1. What are the trends in deployment for each of the four renewable technologies supported by the FIT?
2. Is the FIT driving a build-up of momentum in the FIT-technology sectors?
3. How is the current electricity system responding to the FIT and what impacts are political, economic and socio-cultural developments having on this response?
4. How could policy be improved to further integrate the FIT technologies into the electricity system?

Each research question is addressed in separate chapters. Question 1 in Chapter 6, question 2 in Chapter 7, question 3 in Chapter 8 and question 4 in Chapter 9. Section 4.2 of this chapter provides an overview of the research and the timeframes for fieldwork, analysis and write-up elements of the study. Section 4.3 outlines the conceptual framework that structures the project. Sections 4.4 – 4.6 then detail how each of the three data sources were approached. Section 4.7 explains how the information was analysed using the framework adapted from Kern (2012).

SECTION 4.2 OVERVIEW AND TIMEFRAME

The study period ran from October 2009 until December 2012. The first year of this period was dedicated to a review of the existing academic work related to the history and current status of the electricity system in the UK, theories of lock-in and innovation, theories of socio-technical systems and transition, electricity and renewable energy policy in the UK and Europe, and the design of FITs and alternative support mechanisms. This preliminary review served to develop knowledge of the key elements of the research area, it contextualised the study, and it highlighted the areas in which academic research was lacking. During this review the research questions were continually developed and adapted in response to the existing literature. The GB FIT was introduced during the study period and so there was no academic work reviewed at this stage that addressed the scheme directly, and this thesis therefore makes a clear empirical contribution.

But the review also highlighted the calls within the transition literature to operationalise the theory of the MLP on socio-technical transitions, to move beyond the development of the theory itself and evaluate existing developments in socio-technical systems. The FIT provides a new, interesting and useful focus for this exercise because it is potentially very disruptive for the electricity sector due to the alternative characteristics the FIT technologies represent for the existing regime. It was also introduced within the study period which has allowed for a comprehensive study of the introduction and first two years five months of the mechanism.

Although two years five months is a very short period in which to assess the role of a policy mechanism in contributing to transition, the narrative, contextualised account that this thesis presents makes a contribution to the understanding of the detailed interactions between governmental policy, industry, and technology in periods of change. The research questions, above, have been formulated to fully explore these empirical and theoretical contributions' of the thesis and they have been worded in a concise and coherent manner in order to ensure the "answerability" (Silverman, 2008, p104) of the research.

Following the initial review and the formation of the research questions a research design was constructed which structured the fieldwork phase across 2011. The fieldwork had two distinct aims –

1. To gain *knowledge* of the structure and workings of the electricity sector, and the impacts of the FIT within it;
2. To seek *perspectives* on stakeholders' experiences and views of the role of the FIT in the wider electricity system.

The fieldwork was centred around 37 in-depth interviews with stakeholders in the electricity system but also included attendance at many Government or industry meetings, conferences and events. The research design provided a structure for the fieldwork phase but it was also flexible to allow the study to evolve, develop and unfold as it proceeded. The research design was adjusted throughout the study to allow for the inclusion of people and topics not initially foreseen.

All 37 interviews were undertaken between April and December 2011 and this is therefore the period for which there is the most empirical data. However, this has been supplemented with continued contact with some participants and industry contacts, and also by the analysis of documents and statistics published by the Government and Ofgem. The cut-off point for the research was the end of August 2012, and this thesis therefore reports on the period beginning with the introduction of the FIT on 1 April 2010 up to 31 August 2012.

The 12 months of the study period remaining after the fieldwork were dedicated to the write-up of the thesis. This involved a further review of relevant literature including academic publications covering areas not addressed in the first review, new academic research, and Government publications related to the FIT and wider electricity policy. It also included the analysis of all empirical data using the analytical framework based on the MLP. Data analysis was an on-going process from the start of the fieldwork phase but a focused effort was made to apply Kern's framework during February and March 2012. This is described in detail in Section 4.7 below. The write-up began in March 2012 and was completed at the end of December 2012.

The following section outlines the conceptual framework applied to this research.

SECTION 4.3 CONCEPTUAL FRAMEWORK FRAMING THE RESEARCH

Conventional policy analysis in the energy field is typically based on a quantitative, economic assessment of the costs and benefits of a policy (DECC, 2012). DECC and Ofgem are reporting regularly on the FIT figures with Ofgem releasing a quarterly newsletter outlining the key trends under the scheme (Ofgem, 2012a), and DECC releasing annual, quarterly and monthly statistics, and weekly figures on sub 50kW solar PV installations. These figures provide a useful insight into the progress of deployment under the FIT but they only illustrate a top-level view. The methodological contribution of this thesis is to move beyond a conventional, rigid economic evaluation of a policy mechanism, although aspects of this are included, and to demonstrate a qualitative systems-based analysis that explores the wider significance of the FIT in the UK's transition to a low-carbon electricity system.

The FIT not only exists within a suite of different policies but it is also acting within a complex socio-technical system which contains 'multiple equilibria' that are difficult to bring under analytical control (Schumpeter, 1954 in Arthur, 1984). These multiple equilibria have ontological consequences because they imply that there is no one objective answer or conclusion to be drawn from the process of transition. It is a subjective experience for many varied actors within a socio-technical system of multiple interrelating parts. The role of research within this context is not to unearth the *answer* but to seek to reflect the experiences of the actors concerned and to draw conclusions for the implications for transition. The thesis therefore employs an interpretevist approach which acknowledges that the 'real world' is socially constructed and must therefore be understood through the language, experience and shared meanings of those involved. Interpretive research does not generally predefine variables, but explores the ways in which people make sense of their own world (Gerson and Horowitz, 2002). This thesis does project a predefined structure at the analytical stage but attempts were made during the fieldwork to ensure that participants were given the flexibility and freedom to outline their own experience and perspective on the development of the electricity system and the role of the FIT within that.

Smith et al. (2010) point out that any research into existing systems, such as electricity, will always be '*partial, situated and temporary*', due to their continual development (p. 445). Partitioning the multiple equilibria operating within a socio-technical system will always create analytical challenges that require a reflexive approach by the researcher. The electricity system, the focus of this research, has many aspects that are interrelated and constantly changing, and the system is experienced by different actors in different ways. In addition, the FIT is still an emergent development in the UK energy policy framework and it is therefore still early to draw conclusions from the figures alone. For these reasons a qualitative approach has been taken to this research which builds a narrative account of the FIT so far, allowing space for interpretation of the experiences of stakeholders. As Frank Geels (2010) argues, formal quantitative analyses may only be appropriate for relatively stable socio-technical situations where the parameters are embedded and well known. Emergent transitions that are in progress require a reflexive analysis that only qualitative methods can achieve.

As Fischer (2003) explains –

> "*The key to explaining how **change** comes about has to be grounded in a detailed contextual examination of the circumstances at play in specific cases. For this purpose quantitative methods have to take a back seat to qualitative research*" (p. 108, author's emphasis).

This approach also facilitates the development of a more narrative, social account of transitions which Nye et al. (2010) suggest is lacking from the existing literature.

The following section outlines the reasons why interviews were selected as the primary data collection method for this research and it explains how they were undertaken and what issues arose.

SECTION 4.4 PRIMARY DATA COLLECTION - INTERVIEWS

SECTION 4.4.1 INTERVIEW FORMAT

The primary data for this research was collected from a series of 37 in-depth, face-to-face[14], semi-structured interviews with stakeholders in the UK electricity sector.

The interview is an established technique within qualitative research for gaining rich, complex, subjective and sensitive information (Bryman, 2008; Robson, 2002). As '*conversations with a purpose*' they offer an opportunity to explore a participant's perspective in great depth (Burgess, 1984, p. 102). This was necessary in this study because the FIT, and renewable energy in general, are highly politicised issues that are inherently subjective. The views of a stakeholder are informed by many interrelated factors and it was important to explore these thoroughly, at length, in order to understand each view-point. The interview format fostered the opportunistic exploration of emergent themes and perspectives, whilst providing enough structure to ensure a broad coverage. Each interview lasted between one and two hours which gave enough time to delve into relevant topics, but in a focused manner.

The semi-structured format of interviewing allows for a degree of consistency between interviews which assists the analysis of data (Denscombe, 2007). In this study a set of ten questions were sent to the participant in advance. These were tailored to the expertise of each participant but ensured that the research questions were covered. They were used as a guide for the interview, each question acting as a prompt into a new subject area. It was felt that this approach would produce richer data than a survey-type interview format where

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[14] There were two exceptions. Interview 3 which was conducted by telephone with a participant in Germany and Interview 23 which was conducted by email at the participants request.

identical questions are asked of each participant and the discussion follows a rigid structure. Although this approach produces easily analysable results, it does not allow for the development of ideas and the introduction of new topics during the interview. Equally, an unstructured format was felt to be inappropriate for the purposes of this study. Although these fluid discussions can produce interesting data there is a danger that they can become static or unfocused. This can make the subsequent analysis of data very difficult.

All but two of the interviews were carried out face-to-face and usually at the participants place of work for their convenience and to minimise the drop-out rate. Some of the interviews were undertaken in a public place, at the participant's request. The reason for favouring face-to-face interviewing was two-fold. Firstly, the topics under discussion in this set of interviews were often complex, and occasionally commercially sensitive, and it was felt that a face-to-face approach would lead to a more direct, clearer understanding of what was being communicated from, and to, the participant.

The second reason for choosing face-to-face interviews was that developing trust from the participant was felt to be a critical stage in accessing the more interesting opinions and information (Denscombe, 2007; Bryman, 2008; Robson, 2002). This format allows for subtle affirmation and encouragement of a participant's contributions which leads to more naturally-flowing conversations. But also, it is possible to build trust through choosing an appropriate degree of formality and familiarity in the presentation and conduct of the researcher. For example, participants working in finance, law or Government are generally accustomed to more formal, professional relationships whereas start-up solar PV installers and AD developers are typically more informal and familiar. But each actor is unique and will be more comfortable, and trusting, with a particular relationship style. Gauging this correctly requires a degree of sensitivity and responsiveness on the part of the researcher, which is far easier to achieve in a face-to-face situation than it would be by telephone or email. It is possible to garner key information from the participant's position, role in the sector, or style of email communication but the face-to-face setting is far more telling and it allows the researcher to respond appropriately and build trust as the interview develops.

The one interview that was carried out by telephone, due to the interviewee being in Germany, raised a number of issues. Firstly, the participant was not a native English speaker and it was occasionally difficult to comprehend the finer points of the discussion without any non-verbal expression to assist both parties. But it was also more difficult to keep the interviewee talking. The answers were very concise and closed and it was not possible to encourage further depth through subtle gestures. The participant was also unable to fully verify the identity of the researcher, despite prior communication, and was consequently very careful in responses relating to commercially sensitive information. This lack of trust seemed to significantly affect the quality of responses and justified the preference for face-to-face interviews where possible.

All interviews were recorded, given the participants permission, and fully transcribed soon after. This allowed for a more thorough examination of what was said, aiding the natural flow of conversation and freeing the interviewer up by reducing the need for note-taking, as recommended by both Bryman (2008) and Robson (2002). The transcriptions then became the basis of analysis. In addition, notes were taken during and after the interviews which captured reflections on what was discussed and were revisited during the analysis stage.

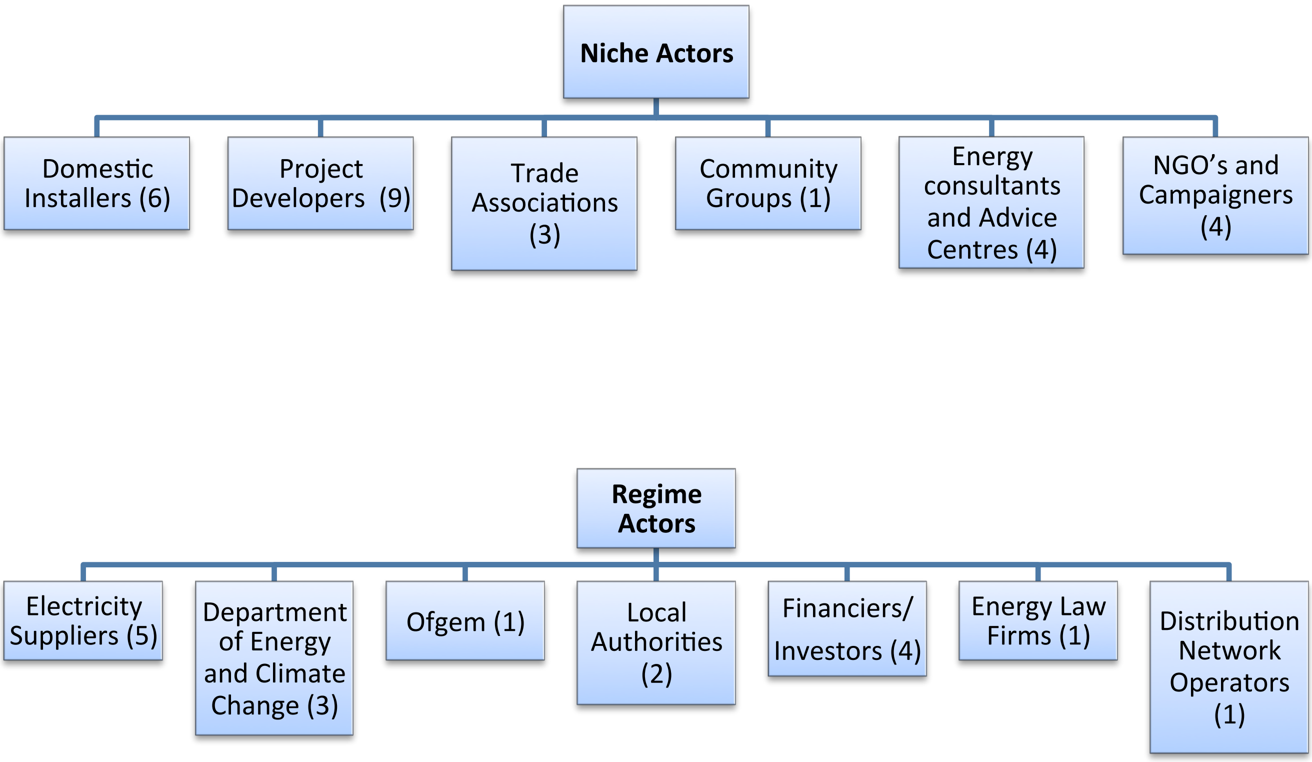
The following section explains how the participants were selected.

SECTION 4.4.2 SAMPLING

In line with the two aims of the fieldwork, stated above in Section 4.1, the interviews were intended to access stakeholders in the electricity sector who could give an informed, rich account of their perspective on the FIT, but also key information relevant to the research questions. The intention was not to survey as many stakeholders as possible, but rather to access sector *elites* who could provide both their own perspective and a useful overview. The aim was to unearth findings that have implications outside of the individual situation – or “*to illuminate the general by looking at the particular*” (Denscombe, 2007, p.36).

However, it was important to ensure that a reasonable range of stakeholders were included so that different perspectives were recorded. To achieve this range, an initial map was developed of the main stakeholder groups in the electricity sector. This map was then split into groups operating at the niche level and the regime level, illustrated below in Figure 4.1. The landscape, as a broad context of political trends, environmental change and macro-economic development, does not contain actors operating at that level and it is therefore not represented specifically here. Rather, it structures all activity at both niche and regime level and participants were therefore asked questions relating to this broader context. Where possible or necessary, multiple participants were selected to ensure triangulation within each group. However, some groups were only represented by one participant if appropriate or due to issues of access. The stakeholder groups are illustrated below with the number of participants per group shown alongside.

FIGURE 4.1 STAKEHOLDER GROUPS



Source: Author[15]

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[15] Note – some participants fall into more than one category e.g. domestic installer and project developer and so the total is greater than 37 participants

SECTION 4.4.3 PILOT STUDY AND CONTACTING PARTICIPANTS

The first interview was conducted on 14 March 2011. This was a pilot interview intended to trial the initial contact approach, question design, and interview techniques. A number of issues were raised in this interview which are detailed below –

- The set of questions were designed to get increasingly complex or involved in order to give the participant a chance to settle into the interview. It was found that too much time was spent on the early questions which were of less value to the research. Therefore, future question sets were designed to have one brief introductory question but then quickly get into the key topics to allow ample time to explore them.
- Some questions were either answered in a very concise, clear manner which needed no expansion or the interviewee chose not to answer them at all. This shortened the interview length, so in all subsequent interviews a list of additional questions were taken in order to keep the conversation flowing.
- It took three weeks from the initial contact to the interview taking place. The participants in this study are involved in a sector that had very recently ramped-up its activity in response to the FIT and they were consequently very busy. It was therefore important to be flexible and patient when contacting potential participants and to leave enough time to work around their availability.

Following on from the pilot interview, stakeholders were contacted in two ways. About half were contacted by email, and then followed up by telephone where possible. This ‘blind’ approach resulted in many negative responses and multiple actors had to be contacted for each willing participant. A more successful method was to approach potential participants at industry meetings, events or conferences and request an interview in person. It was far easier to get a positive response after an initial informal discussion and brief explanation of the research. This also allowed a more focused selection of interviewees because many actors were approached before deciding which ones would be asked to participate. About half the interviews were set-up in this way.

The interviewees were thus purposively selected but every attempt was made to ensure a range of views were represented. Firstly, the stakeholder groupings ensured that different roles within the sector were included. But also, the split between niche and regime groups ensured that diverse opinions and drivers were reflected in the data. A full list of the interviews, including the interview number which is used in the analysis, is in Table 4.2 below.

TABLE 4.1 PARTICIPANTS

Interview Number	Position	Company/Organisation
1	System Design Operative	Solar PV domestic installer and stand-alone developer
2	Head of Planning	Local Authority
3	Managing Director	Stand-alone solar PV developer
4	Head of Policy	Big 6 Electricity Supplier
5	Managing Director	Micro-hydro developer
6	Head of Regulation	Big 6 Electricity Supplier
7	FIT Campaigner	Environmental NGO
8	Academic and FIT campaigner	University
9	Business Development Manager	Solar PV project manager and developer
10	Chief Scientist	Environmental NGO
11	Director	German-based solar PV developer
12	Consultant	Energy Supplier Consultancy
13	Policy manager/financier (secondment)	DECC/Accountancy Firm
14	Chief Executive	Renewables Trade Association
15	Developer	Small-scale wind developer
16	Managing Director	Renewable energy investment fund
17	Chief Executive Officer	Renewable electricity supplier
18	Official	Office for Renewable Energy Deployment, DECC
19	Senior Official, FIT Team	Office for Renewable Energy Deployment, DECC
20	Partner in Corporate finance, infrastructure and renewable energy investment	Accountancy Firm
21	FIT Campaigner	NGO
22	Generation Strategy Project Manager	Big 6 Electricity Supplier
23	Official	FIT Compliance, Ofgem
24	Energy Manager	Local Authority
25	Energy Lawyer	Law Firm
26	Chief Executive	Energy Advice Centre
27	Energy Consultant	Trade Association/Consultancy
28	Fund Manager	Renewable Energy Private Equity Firm
29	FITs Project Developer	Wind Developer
30	Consultant	Community Energy Consultancy
31	Innovation and low carbon networks manager	DNO
32	Director	Domestic renewables installer
33	Managing Director	Solar PV developer
34	Developer	AD Developer
35	Founder	Domestic solar PV installer
36	Chairman/Generator	Trade Association/hydro-scheme
37	Head of AD	Trade Association

SECTION 4.4.4 ETHICS AND CONSENT

In line with the University of Exeter Department of Geography's (now School of Geography, College of Life and Environmental Sciences) ethical guidelines, a full consent form and Statement of Ethical Approval were taken to each interview.

The purpose, and a summary, of the research were outlined in the initial email sent to participants and then explained at the start of every interview. In addition, anonymity was offered to every participant and it was explained that if any information was unsuitable for inclusion it would be removed at the participant's request. Also, the participant was given the option to terminate the interview at any time without explanation.

All the interview recordings, names and transcripts have been stored according to the stipulations of the Data Protection Act 1998. Any information or quotes included in this thesis have been anonymised to protect the participants and all materials will be destroyed two years after the completion of this research.

At all stages, every effort was made to ensure the participant was comfortable and willing to remain part of the research. No undue pressure was placed on participants to answer specific questions or discuss sensitive matters. Any information communicated 'off the record' was kept confidential and no data, other than that included in this thesis, has been shared with any other parties.

SECTION 4.5 MEETING ATTENDANCE

An important aspect of the fieldwork, and a critical source of data, was attendance at a number of meetings, events, conferences and shows. These events served multiple purposes. They provided up-to-date information on developments under the FIT from the perspective of both industry and Government, they presented an opportunity to ask specific questions of panellists and attendees, they provided a platform for observing the interactions between different stakeholders, they were a forum for meeting many stakeholders to discuss the FIT scheme and to identify potential participants, and they were an opportunity for the researcher to become established as a recognised actor within the relatively small and familiar renewable energy sector. This last point was important for gaining access to busy stakeholders by increasing the perceived professionalism and legitimacy of the researcher. This helped to overcome the issues of access that resulted from blind email approaches to stakeholders. Some of the fieldwork events are listed in Table 4.2 below.

Notes were taken in a field diary throughout the fieldwork events. Contributions included facts, figures, and contacts; and observations on stakeholder interaction, key discussion topics, and attendee frustrations or areas of optimism. These notes have been built into the analysis, described in Section 4.7.

TABLE 4.2 FIELDWORK EVENTS

Date	Event	Details
23 March 2010	FIT and RHI Consultation Event, Bristol	Details of the FIT scheme were discussed with DECC officials the week before the scheme was launched.
23 November 2010	Renewable Futures, Bath	Regen SW conference
12 January 2011	Parliamentary Renewable And Sustainable Energy Group (PRASEG) and Business Council for Sustainable Energy (BCSE) Conference, London	Electricity Market Reform conference
22 January 2011	Wadebridge Renewable Energy Network (WREN) Launch, Cornwall	Launch event for Cornwall community energy project
27 January 2011	ResGen Cornwall Renewable Energy Breakfast, Cornwall	Roundtable on renewable energy industry requirements in Cornwall
2 March 2011	Taking advantage of FITs at Ecobuild, London	FITs workshops at sustainable building conference
16 June 2011	Funding Renewables, London	Energy and Utility Forum conference
20-21 June 2011	Microgeneration UK, London	Micropower Council conference
22 June 2011	PRASEG PV Legal, London	Roundtable on legal aspects of solar PV development
29 June	British Hydropower Association Conference, Cardiff	Industry conference on micro-hydro
5 July	Renewable Solutions, Bristol	Regen SW renewables industry conference
7 July	PRASEG Annual Conference, London	Energy Policy Conference
28-29 July	Cornwall Renewable Energy Show, Cornwall	Cornish industry conference and trade show
12 October 2011	Decarbonising the Power Sector, London	British Institute of Energy Economists (BIEE) seminar on the economics of electricity policy
9 November 2011	Renewable Futures, Exeter	Regen SW renewable energy conference
8 December 2011	Green in the City Forum	UK Solar Investment Forum
23 January 2012	Ministerial Contact Meeting, London	The Decentralised Energy Ministerial Contact Group (DECG) meeting discussing the requirements of decentralised energy
17 April 2012	The future of large-scale solar, Bath	Carbon Catalyst industry event
2011-2012	Bristol Energy Network and Bristol Energy Co-op, Bristol	Multiple events with Bristol community energy groups

SECTION 4.6 ANALYSIS OF DOCUMENTS, STATISTICS AND CONSULTATION RESPONSES

The previous two sections have outlined the ways in which the interview process was designed and undertaken, and the value of attending industry meetings and events. This section details the final source of data for the study which is the analysis of consultation responses, documents and statistics published by Government and Ofgem. The literature review includes Government documents that are relevant to the research questions or the development of electricity policy leading up to the FIT but this section describes how documents were analysed and built in to the analysis.

The analysis of documents, consultations, and press releases from Government and Ofgem added a further level a triangulation to the research. These sources have been used extensively to provide information on the workings of the FIT but they have also been interpreted as the views of Government and the regulator. In addition, statistics and reports released by these two institutions have been analysed and used widely as primary evidence.

There have been six consultations related to the FIT which have all been analysed. They are listed below –

1. Consultation on Renewable Electricity Financial Incentives, opened 15/07/2009 (DECC, 2009).
2. Consultation on fast-track review of Feed-in Tariffs for small scale low carbon electricity, opened 18/03/2011 (DECC, 2011e).
3. Consultation on a change to the rules on the treatment of extensions to installations under the GB Feed-in Tariffs scheme, opened 27/07/2011 (DECC, 2011f).
4. Comprehensive Review Phase 1: Consultation on Feed-in Tariffs for solar PV, opened 31/10/2011 (DECC, 2011g).
5. Consultation on Comprehensive Review Phase 2A: Solar PV cost control, opened 09/02/2012 (DECC, 2012d).
6. Consultation on Comprehensive Review Phase 2B: Tariffs for non-PV technologies and scheme administration issues, opened 09/02/2012 (DECC, 2012e).

DECC released the industry consultation responses for the first consultation, and it has published a summary of responses for the other five. In addition, it has been possible to gain access to some responses through the respondents themselves. These documents have been analysed in the same way as the interview transcripts. This is described in detail below but briefly, the key points and themes from each response are pulled out and placed within constantly evolving categories. In this way, the perspectives detailed within the responses are recorded as another stakeholder perspective. This has both supported and challenged the information received from the other data sources, which has triangulated the findings.

The following section details the data analysis process in more detail and it outlines the way in which Kern's analytical framework was applied to the data from this research.

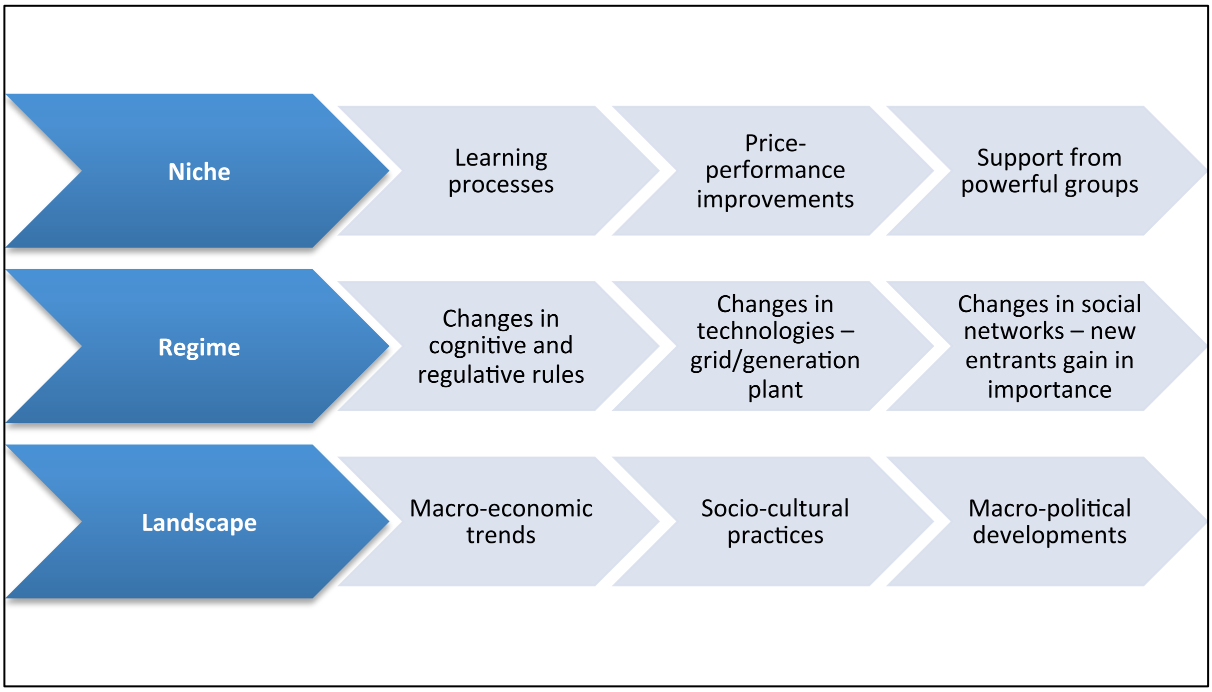
SECTION 4.7 DATA ANALYSIS AND APPLICATION OF THE ANALYTICAL FRAMEWORK

SECTION 4.7.1 CATEGORISING DATA AND ANALYSIS

The length and depth of the fieldwork stage generated a huge volume of material to process and analyse. The first stage of analysis was to read through all materials in order to "*gain an overview of data coverage and become thoroughly familiar with the data set*" (Ritchie et al. 2003, p.221). But it was then necessary to find a way to synthesise and condense the data into a more manageable form and ensure that all work was structured around the research questions.

The approach taken in this analysis was based around an adaptation of Florian Kern's analytical framework, which he applies to the work of the Carbon Trust. The framework is structured around the MLP levels of niche, regime and landscape. Within each of those levels transition scholars have identified a number of processes that are required steps in the course of transition. Those processes are the basis of this framework and they structure the analysis of the data from this research. The framework, and the MLP upon which it is based, is discussed in detail in Chapter 3. The framework is illustrated below in Figure 4.2.

FIGURE 4.2 ANALYTICAL FRAMEWORK



Adapted from Kern (2012)

In brief, the data was organised into categories which fit with the processes identified in the analytical framework such as Learning Processes; Changes to Regulation; and Macro-economic developments. At the start of this process NVivo 9 analysis software was used to assist in the organisation of data. This software is designed to break data-sets down into groupings at various levels and then look for and examine any relationships in the data. NVivo is a very useful tool for working with large data-sets and it allows the researcher to break information down into classifications. But it uses a linear system for organising data that was found to be difficult to work with in this case. At the early stage of this analysis it was necessary to be able to see each point/perspective and to be able to move it around or duplicate it. It was decided quite early on that a less linear, more tactile method would be used to organise the data.

The approach taken was to copy each point/perspective from the materials onto a card and a simple coding system was devised which recorded the name and position of the interviewee and where in the interview, or document, the quote was found. All materials were then processed in this way, pulling out the key points. These cards were then organised into the basic groupings in Kerns's framework. Those groupings were then split into more specific titles such as FIT Changes; FIT Campaign; Commercial Innovation; Technological Innovation etc. Although this process was time consuming it enabled the researcher to spread the work out and move ideas around physically, creating an evolving map of the issues being discussed by participants, or recorded in documents and notes.

This was a critical stage of the analysis because it took the themes emerging from the data and applied them to predefined categories. This required reflexivity to ensure that all quotes and information were not taken out of context or applied inappropriately. Every effort was made to maintain a balanced, open approach that avoided any '*holistic bias*' where all findings '*seem to fit into the picture; achieved by ignoring the things that don't*' (Robson, 2002, p.152). All perspectives were built into the groupings, including instances where participants did not discuss an area covered by the framework. For example, if during an interview there was no mention of powerful groups moving into the FIT space, then this was recorded as a finding in itself. However, due to the pre-defined nature of the categories, there is a danger that any mention of an area that concerns the research is highlighted beyond its intended emphasis. Ameliorating this bias was a constant consideration and every effort was made to reflect the true perspective of each participant.

The titled groupings within the analytical framework were finally entered into a database and all quotes and pieces of information that were included in that grouping were collected under each title. A small example of this database is shown below in Table 4.3. This database helped the write-up process by placing all categorised materials together, in an easily referenced format.

TABLE 4.3 EXAMPLE ANALYSIS DATABASE – NICHE LEVEL

Support from powerful groups
Supplier role
'*We are one of the biggest players but still only 2% of the market. It is naturally very fragmented and we've struggled to find a way of scaling-up our operation*' (Interview 6).
FIT risk is not significant for us compared to issues such as the German nuclear decision – this has changed everything and opened up new potential for alternative technologies (Interview 8).
'*I think it's fair to say it's had an impact in terms of introducing significant costs in terms of being able to comply with what the licensed suppliers have to do. It's been quite burdensome because it hasn't been implemented well, and then subsequently after its implementation it's now been subject to a number of changes and is likely to be subject to more changes. So it's had a negative impact on the (supplier) sector in the round*' (Interview 12).
Niche Resistance
'*I often go to the Regen South West conferences and 5 years ago it was very much Local Authority players, a few committed individuals and that was about it. Now there are a lot of lawyers and investment bankers. Unfortunately we have to accept that these people need to be in this market for this to become a fundamental element of the British economy and if you want to become a low carbon economy you've got to have those people in the room. So I suppose it's good that they're there and they're seeing that potential*' (Interview 24).
Local Authority role
'*FITs and Local Authorities go hand in hand because they're the people that can come in and deliver schemes. Except they can't because they don't have the expertise, the staff, the skills, the access to funds*'. (Interview 27).
When Chris Huhne came in and changed the 1974 regulation banning authorities from selling power a door was opened for renewable projects e.g. Birmingham. This is back-peddling on privatisation (Interview 9).
The council has a carbon reduction target so they are driven by tonnes/£. Solar PV is a sideline that is seen as a way of bringing in cash but not part of wider strategy (Interview 24).

Once the material was organised and classified in this way the dataset was then processed again in order to extract additional classifications or points. It was then possible to begin to look for relationships between the data in each separate classification to uncover any connections, themes and patterns. Although attempts were made to remain open during this process, the distinction made early on in the research between niche and regime actors did influence the analysis. The material naturally fell into these two broad perspectives as a result of the researchers own classifications but any exceptions to this broad grouping were noted and every effort was made to avoid the anecdotalism that Silverman warns against in qualitative research (2001). Similarities between various perspectives were pulled out and any disagreement was recorded. The core ideas and stories then began to emerge and were allowed to challenge the original research questions and theoretical framework, and to shape the thesis structure.

SECTION 4.8 CHAPTER SUMMARY

This chapter has outlined the methodology applied to this research and it has explained the methods used to collect and analyse data. An interpretevist, qualitative approach has been taken which does not seek to find one answer but rather presents the perspectives of multiple actors and draws conclusions from those accounts. The chapter explained the interview format and the sampling approach used, and discusses the value of the fieldwork events to developing a broad understanding of the research. The way in which Government documents and consultation responses were built into the research was outlined, and finally the analysis of data and the application of Kern’s analytical framework is explained. The research design, including data collection and analysis, is unique and it was important to clarify why each decision was taken and why each method was selected. The next chapter presents the RE policy background to the FIT and then introduces the FIT scheme in detail.

Chapter 5 Renewable Electricity Policy in the UK and the Feed-in tariff

SECTION 5.1 CHAPTER INTRODUCTION

This chapter outlines the different forms of governmental support for RE at all scales in the UK over the last twenty years. In order to understand the role of the FIT within electricity system transition it is necessary to place the mechanism within the context and history of RE policy in the UK. This is because the introduction and design of the FIT is partly a response to the failure of previous policy to deliver small-scale RE. This chapter briefly discusses the Non-fossil fuel Obligation (NFFO), which was the first support mechanism introduced in 1990, exploring the design of the mechanism, its impacts and its influence on future renewables policy. It then outlines the design and impacts of the RO, which is still the principal support mechanism in the UK for RE above 5MW. The governmental support for micro-generation and small-scale RE that preceded the FIT is then briefly discussed followed by a detailed explanation of the design of the GB FIT and the changes that have been made to the mechanism since it was introduced.

The structural, market and regulatory barriers that are specific to small-scale RE have been recognised by the regulator (e.g. Ofgem, 2007), Government (e.g. DTI, 2007), in academic research (e.g. Foxon et al. 2005a); and by industry (e.g. DECG, 2012). But as Chapter 2 discussed, RE at all scales faces barriers to deployment. It is therefore necessary to either change the market that creates the barriers or to create a proxy which bypasses or compensates for it. The latter is effectively the role of renewables policy in the UK and various support mechanisms have been tried, tested, reviewed and abandoned since the first mechanism, the Non Fossil Fuel Obligation (NFFO), was introduced in 1990. The following section explains how the NFFO worked, the capacity it delivered, and the reasons why it was replaced. It is useful for this study to look at previous approaches to renewables support because they are responsible for the current status of RE in the UK and because policy is often designed to resolve the problems of the previous policy.

SECTION 5.2 THE NON FOSSIL FUEL OBLIGATION

The first support mechanism for RE in England and Wales was the NFFO which ran from 1990 to 1998. Similar mechanisms were also introduced in Scotland (Scottish Renewable Order) and Northern Ireland (Northern Ireland Non-Fossil Fuel Obligation). The NFFO was designed to subsidise nuclear and renewable electricity generation through placing an obligation on electricity suppliers to buy all NFFO output offered to them. It stemmed from a recognition that the nuclear industry was not commercially competitive and that it would need to be subsidised post-privatisation if it was to survive. The RE element was belatedly added to the NFFO in order to placate European Commission concerns that the nuclear industry was being unduly supported and in response to lobbying from some renewable generators and civil servants (Mitchell, 2000; Mitchell et al, 2010; Agnolucci, 2007). However, what resulted was a support mechanism that did stimulate some development of renewable capacity, although it underperformed as a result of the mechanism's design.

In brief, the NFFO encouraged renewable capacity through a series of five NFFO Orders. Each Order contained a number of contracts that were decided through a competitive bidding process split into technology bands. Prospective renewable generators would bid a price at which they were prepared to generate (p/kWh) and the winning bid(s) would set the contracted price for power. The winning generator would then be paid this price per unit by the Regional Electricity Companies (suppliers). The Regional Electricity Companies would then be reimbursed the difference between the average monthly pool selling price for power and the contracted NFFO price. The reimbursement came from the Non-Fossil Purchasing Agency[16] funded by the Fossil Fuel Levy, paid from electricity customer's bills. The difference between the pool price and the NFFO price is effectively the subsidy (Mitchell, 2000).

The first two NFFO Orders offered contracts only until 1998 which is a very short time in which to recoup investment in capital intensive RE projects. Consequently the bids were relatively high and the contracts expensive. The following three Orders offered support for fifteen years plus a five year period to build the project which resulted in lower contract

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[16] The Non Fossil Purchasing Agency still exist to administer the NFFO and Scottish Renewables Obligation contracts

prices. A critical objective of the NFFO was to reduce costs per unit generated from RE in each Order. This driver, in addition to the competitive nature of the contract bidding, resulted in the deployment of the more mature technologies, specifically onshore wind and landfill gas (Agnolucci, 2007).

In addition, the competitive bidding process encouraged developers to make very low bids in order to secure the contract. Many of these projects failed to commission either because they were not financially viable in practice, or because they could not gain planning permission (Mitchell et al. 2010). There was no penalty on developers who did not commission which may be why many bids were overly optimistic. The result was that 818MW of RE capacity was deployed under the NFFO, missing its target of 1500MW (Agnolucci, 2007).

The NFFO was competitive in terms of the bidding process but renewable generators were effectively protected, and kept separate from, the electricity markets. Regional Electricity Companies had to buy all NFFO power regardless of where, when and how it was generated. There was a feeling within the new Labour Government, who came into power in 1997, that RE should integrate more with the electricity market in order to drive cost reductions and to reduce customer costs. In addition, the change in market arrangements from the Pool to NETA removed much of the legal and regulatory basis for the NFFO and a new mechanism was designed to fit in with the new arrangements (Mitchell, 2000; Mitchell et al., 2010). This is relevant to this research because it impacted on the design of the RO, which in turn has impacted on the need for, and design of, the FIT mechanism.

SECTION 5.3 THE RENEWABLES OBLIGATION

The current mechanism of support for RE over 5MW in the UK is the RO which was introduced in 2002. The RO is a legislated obligation for electricity suppliers to purchase an annually increasing percentage of their supply from renewable generation or to pay a penalty. Since its introduction the scheme has increased renewable generation capacity from 3.1GW to 13GW at the start of 2012 (DECC, 2012). But as this section explains, the RO is a complex mechanism that was designed to deliver large-scale mature technologies owned by large-scale established companies. It has not provided adequately for a wide deployment of smaller scale, independently owned generation. It is important to explain the background and design of the RO because the FIT was introduced largely in response to its failure to deliver widespread deployment of small-scale RE. It also still operates alongside the FIT for larger-scale technologies and it therefore has an impact on the role of the FIT within electricity system transition and therefore the analysis in this thesis.

SECTION 5.3.1 DESIGN OF THE RENEWABLES OBLIGATION

When the RO was first introduced complying generators received a Renewable Obligation Certificate (ROC) for every MWh of metered, generated electricity, regardless of technology type. These ROCs are then sold to suppliers either directly or through a trading market. Suppliers have to demonstrate compliance with the RO by presenting an appropriate number of ROCs to meet their obligation. Thus ROCs have a commercial value and their sale to suppliers is how generators receive the subsidy (DECC, 2012).

A key feature of the RO is that suppliers have the option of buying out of their obligation through paying a fixed penalty for each MWh they do not meet through presentation of ROCs. This 'buy-out' effectively sets a cap on the price a supplier is prepared to pay for RE above the price of conventional power – if the electricity costs more than the buy-out price the supplier will choose not to meet their obligation[17] (Mitchell et al., 2006). In addition, because the RO does not include a guarantee of offtake, independent generators are left significantly exposed to the market price for power. In order to address this risk, renewable generation will either have a long-term Power Purchase Agreement (PPA) with a supplier, effectively a contract for offtake that builds in a penalty for the risk of balancing the power taken on by the supplier, or, more often, the generation will be owned by a vertically integrated utility that can manage the renewable power as part of a larger portfolio of generation. In this way, the design of the RO penalises independently owned renewable generation (ECCC, 2011).

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[17] The buy-out price was set at £30/MWh for the period 2002-2003 and is uprated each year in line with inflation (see Table 1).

The buy-out revenue that is raised from suppliers' failure to meet their obligation is recycled back to the participating suppliers through Ofgem. They receive a percentage of the revenue equivalent to the number of ROCs they submitted. This recycling of funds was designed to further incentivise participation in the scheme through providing an additional revenue stream for suppliers (Ofgem, 2009). However, the buy-out revenue varies each year according to how all suppliers have chosen to meet their obligation. This variation in buy-out revenue impacts on the amount that suppliers are prepared to pay for renewable power, and therefore creates a fluctuation in the value of ROCs. This fluctuation creates uncertainty for generators over what price they will receive, and thus increases risk for investors over the returns from the project (Mitchell et al. 2006; Toke, 2007). Any increase in risk will raise the risk profile of investment in renewable projects, and thus the cost of capital increases. Again, the risk is easier to manage as part of a larger portfolio of generation and with a vertically integrated supply business guaranteeing offtake and small or independent generators are therefore disincentivised.

SECTION 5.3.2 THE IMPACT OF THE RENEWABLES OBLIGATION

The RO was designed as a competitive mechanism to deliver renewable supply at minimal cost. But different renewable technologies are at different stages of development and need different levels of support. The RO, in its initial design, did not compensate for this and has therefore only supported relatively mature technologies (DECC, 2010a). But the RO has undergone regular reviews and changes since its introduction in 2002. The most significant change was the introduction of banding by technology which means established technologies receive fewer ROCs per MWh and emerging technologies receive more. For example landfill gas receives 0.25 ROCs/MWh, onshore wind receives 1 ROC/MWh and tidal stream receives 2 ROCs/MWh (DECC, 2012). The levels of banded support have recently been reviewed for the final period of the RO, 2012 – 2017, before it is replaced by the CfD mechanism described in Chapter 2.

The fluctuating returns that renewable generators can expect from their output have meant that investment in RE has been a complex, high risk process that has favoured large established companies who can roll renewable projects up into a wider portfolio of investments to spread the risk, and finance them from their own balance sheets (Hain et al., 2005; Mitchell et al., 2006 and 2010). This has come at the expense of new, innovative market entrants who have mostly been unable to raise finance due to the inherent risk within the RO. Before the FIT was introduced this created a concentrated RE market dominated by the Big 6 and a few large independent generators (DECC, 2010a).

In summary, the RO is a mechanism that was designed to deliver low cost renewable generation driven by establishing a competitive market. It has resulted in some development of the large-scale ‘low-hanging fruit’ of renewable sources, primarily by established companies but it has not stimulated a radical innovation in the electricity system (Hain et al. 2005; Toke, 2007). It has not encouraged new entrants or less developed technologies due to the costs, complexities and risk of participating in the scheme (Mitchell et al. 2010). DECC state that the RO *‘can be difficult to understand and navigate for those not familiar with the electricity market, and at the very small scales the returns offered were not sufficient to justify investment* (DECC, 2010a, p. 1). Small scale RE (sub 5MW) and microgeneration (sub 50kW) technologies have been treated separately from larger scale RE, but they have received inconsistent support prior to the FIT. This support is outlined below.

SECTION 5.4 POLICY SUPPORT FOR SMALL SCALE RENEWABLES BEFORE THE FIT

Three separate capital grant schemes provided support to microgeneration and small-scale RE prior to the introduction of the FIT in 2010.

1. From 2002 – 2006 the Major Photovoltaic Demonstration Programme provided capital grants to individuals and organisations for up to 50% of PV installation costs. The scheme aimed to bring forward 3,000 domestic/individual systems with a total capacity of 6MW and 140 medium and large scale non-domestic systems with a total capacity 3MW. The scheme ran for four years with a total budget of £31 million (EC, 2005).
2. Another grant scheme called Clear Skies ran alongside the Major Photovoltaic Demonstration Programme from 2002 – 2006. The scheme was funded with £10 million by the Department of Trade and Investment and administered by BRE

(Building Research Establishment). It provided householders and communities with grants up to 50%, or £100,000, for non-PV technologies including solar thermal, wind, small-scale hydro, biomass and ground source heat pump installations (BRE, 2006).

3. In April 2006 these two schemes were superseded by the Low Carbon Buildings Programme (LCBP) which was implemented under the 2006 Microgeneration Strategy (DTI, 2006). The LCBP was administered by the Department for Business, Enterprise and Regulatory Reform (BERR) and it supported solar PV, wind, small hydro, solar thermal, ground source heat pumps, and wood or wood pellet fuelled stoves and boilers. Grants up to 50% of the cost of installation were awarded to households and up to 40% for commercial organisations. Due to high demand in the early months of the scheme a cap was introduced which limited grants to £500,000 per month. This led to a rush of applications at the start of each month which drained all available funds, followed by a hiatus in activity. In March 2007, the entire LCPB monthly budget was allocated in just 2 hours. This was difficult for the small, establishing industry to work with so the scheme was reviewed in April 2007 and reintroduced in May with sharply reduced grant levels which resulted in a collapse in installation numbers (Jardine and Bergman, 2009).

These three grant schemes provided stop-start support for small-scale RE that resulted in some modest increases in microgeneration, in particular solar thermal. Table 5.1, below, shows an estimated total number of microgeneration installations at the end of 2007, before the LCBP was reduced. This is relevant to this research because it provides an estimate of the installation numbers before the FIT was proposed, designed and introduced.

TABLE 5.1 ESTIMATED MICROGENERATION INSTALLATIONS BY 2008

Technology (sub 50kW electric/45kW thermal)	Number installed by 2008
Solar PV	2300
Micro-CHP	200-1000
Micro-wind	1100
Micro-hydro	65 – 75
Solar thermal	90,000
Biomass boilers	500-600
Ground s-source heat pumps	745-2000
Air-source heat pumps	150
Estimated Total	95,000 – 98,000

Source: Bergman and Eyre (2011)

The microgeneration and small-scale RE industries were still in their infancy in 2007 and the aspirations of these three grant schemes had achieved only gradual, inconsistent development in the sector (Bergman and Eyre, 2011). Many actors within, or concerned with, the sector were calling for more directed and stable support for microgeneration and many actors were also arguing that the RO only delivered mature, large-scale technologies that were utility owned.

In response to these criticisms of the RO a Renewable Obligation Order was introduced in April 2007 to each of the three separate RO schemes in England and Wales, Scotland, and Northern Ireland. The Order introduced a number of changes including the allowance of agents to act on behalf of small generators (<50kW) and to receive ROCs (Ofgem, 2009a). These agents could amalgamate output from multiple generators for the purpose of obtaining ROCs. This improved the support provided by the RO for small generators because it reduced the administrative burden and effectively allowed them to outsource the application for, and selling of, ROCs. In addition it meant that generating units would be added together leading to a reduction in the rounding errors that could punish generators at the smaller end (Micropower Council, 2005). It also reduced the transactional costs that had previously disproportionately affected smaller generators – before the Order was introduced the time and costs of obtaining accreditation for ROCs was similar, regardless of the size of the generator and the eventual return they would accrue from selling the ROCs (DTI, 2005).

The result of the Renewable Obligation Order was that Ofgem saw a significant increase in the number of small generators applying for accreditation and therefore the administrative work required to process them. The regulator argued that the administrative burden from small generators was too large relative to the capacity they provide. In the 2007 – 2008 Renewable Obligation Annual Report Ofgem indicated that small generators occupied 75% of their administrative time, 50% of the RO's administrative costs but comprised less than 0.2% of the total RO generating capacity and less than 0.05% of ROCs issued in 2007-08 (Ofgem, 2009a). The total cost of administering the small generators was £650,000 in the 2007-08 period, but only £400,000 of ROCs were issued for their generation (assuming a value of £52.95 per ROC) (Ofgem, 2009a). Therefore the costs of encouraging small generators into the RO, a scheme principally designed for large-scale RE, outweighed the generation that they provided.

It is likely that this burden on Ofgem, and the costs involved, played a role in the Government's decision to introduce a FIT mechanism designed exclusively for smaller generators (although the final design included generators up to 5MW which was larger than the distinction made in the RO Order discussed above; sub 50kW). The experience of encouraging small generators into the RO proved to DECC and Ofgem that there were design issues with the scheme for small-scale RE. A separate mechanism for small and large RE would allow policy-makers to tailor the accreditation process to the needs of each technology scale rather than trying to fit all technologies under one scheme, thereby reducing the administrative work and costs.

The signing of the EU 20:20:20 targets in 2007 (discussed in Chapter 1 Section 1.3) had created pressure on the UK Government to consider all available options for RE deployment, including at the smaller scale. In addition, the various attempts at supporting microgeneration or small generators, outlined in this section, had proven the desire within the RE sector for directed support. There was therefore an increasing pressure on

Government to introduce a FIT mechanism and this became focused in a targeted campaign for the introduction of a FIT. This is explained in the following section.

SECTION 5.5 FEED-IN TARIFF CAMPAIGN

A coalition of organisations and individuals began a campaign in 2007 to introduce a FIT to the UK RE policy framework in order to address the difficulties of the RO and the LCBP for the sector. Some of the main organisations in the coalition were Friends of the Earth, the Renewable Energy Association, the World Future Council, The Country Landowners Association, Greenpeace, Co-op Bank and Alan Simpson MP.

Within this coalition there was a range of motivations, discussed in the interviews for this research, behind supporting a FIT including –

- Challenging the market dominance of the Big 6 energy suppliers and placing greater powers with the individual;
- Separating small-scale technologies from the RO because they were taking up too much of Ofgem's time but only delivering a small percentage of the capacity;
- Mobilising a wider variety of potential sites and pools of investment than were being reached by the RO, including a £200 million fund specifically for small-scale RE at the Co-op bank;
- Stimulating the meso-level of RE development, which is the scale between microgeneration and large-scale utility projects.

The outputs of the campaign included a number of papers, reports and letters, and Alan Simpson MP worked towards gaining cross-party, and cross-house, political support in Parliament. A significant amount of political pressure built up on the Labour Government to introduce a FIT and soon after DECC was formed legislative provision for a FIT was included in the Energy Act 2008. The Act received Royal Assent on 26 November 2008 and the scheme was introduced on 1 April 1 2010, 16 months later.

This campaign has importance for this research because the manner in which the scheme was designed, and subsequently the impacts it has had, was a result of both the diversity of motivations driving the FIT campaign, and the speed with which the mechanism was consulted on and introduced.

DECC were designing a mechanism that had been proposed by a diverse coalition of civil society, industry and political actors with individual motivations of their own. DECC were also trying to work the scheme around their own broader objectives at a time when the Labour Government were coming towards the end of their time in power. It was suggested by several interviewees that this was unstable political ground on which to build a solid, reliable renewable support mechanism and that some of the problems the scheme has faced, in terms of stability, can partly be traced back to this beginning.

The theoretical advantages and design options of a FIT mechanism are explored in the following section.

SECTION 5.6 FEED-IN TARIFF THEORY

FITs are widely used mechanisms for stimulating RE development. According to the European Commission '*well adapted FIT regimes are generally the most efficient and effective support schemes for promoting renewable energy*' (EC, 2008). The central principle of a FIT is to offer a guaranteed price, or tariff, for each unit of electricity generated from a particular source or technology. The tariffs are usually differentiated by technology, and the size of the installation, and also in some cases by the quality of the resource or the location of the project (Couture and Gagnon, 2010; Mendonca, 2007; Fouquet and Johansson, 2008; Langniss et al, 2009). Most FITs also guarantee offtake, removing one of the principal risks for a power project. The differentiated structure of a standard FIT design is intended to stimulate investment in a wide variety of technology classes by a diversity of investors (Tamas et al., 2010; Frondel et al., 2010; Lesser and Su, 2008; Toke, 2007; Middtun and Gautesen, 2007; Mitchell et al., 2006).

The provision of guaranteed prices and buyers for the lifetime of RE projects significantly reduces the risk of investment in power schemes and provides a high degree of security over future cash-flows (Mendonca, 2007; Lesser and Su, 2008). This is particularly valuable for financing capital-intensive projects such as RE schemes which have high upfront costs and a high ratio of fixed to variable costs, as discussed in Chapter 2 (Couture and Gagnon, 2010). Providing secure, fixed returns lowers the risk profile of a power project such that debt finance can be brought in to an investment at a lower rate than equity, increasing the returns for investors. These higher returns can encourage increased investment in FIT-supported projects.

FITs, like all RE support mechanisms, require intervention from policymakers because their central attributes must be defined administratively; specifically for FITs *payment amounts* for individual technologies (e.g. wind, solar, hydro), *payment structures* (e.g. fixed or declining) and *payment duration* (e.g. 25 years). This requires a considerable amount of speculative forecasting of future market conditions, cost reductions and rates of technological improvements (Lesser and Su, 2008). This forecasting has been a central issue for the impacts of the GB FIT which is explained in Chapter 6.

FIT mechanisms generally fall into two broad categories. *Fixed price models* offer a guaranteed set price that is independent of the market price for power (e.g. Germany, UK). This is a stable, low-risk model that provides secure returns for investors and shields generators from the volatility of the power markets. But fixed FITs can become inefficient if the power price falls or ineffective if it rises, lessening the incentive of the tariff. *Premium price models* provide a constant premium over the fluctuating market price of electricity (e.g. Czech Republic, Estonia). It effectively tops-up the price that generators receive for their power and these models therefore tend not to include a guarantee of offtake. There is a greater exposure for generators to the volatility of the power markets which is intended to incentivise RE generators to produce energy when it is needed most (Klein, 2008, Couture and Gagnon, 2010).

This thesis argues that FIT mechanisms are particularly appropriate for the support of small-scale technologies because they insulate projects from the type of issues identified in Chapter 2. As that chapter indicated, the market design, industry structure, investment practices, and physical infrastructure that exist in the current electricity system in the UK have co-evolved to create a lock-in to large-scale technologies. If small-scale RE is to be deployed at scale then targeted support is required that either removes the risks that these system elements create, or compensates for them. It is argued here that FITs can achieve this by providing a guaranteed buyer for power, and a high degree of certainty over the approximate returns a project will make. This means that generators do not have to engage in the electricity market and investors have a secure basis on which to invest (Mitchell et al. 2006).

The following section explains the design of the GB FIT that provides the focus of this thesis.

SECTION 5.7 THE GB FEED-IN TARIFF

SECTION 5.7.1 DESIGN OF THE FEED-IN TARIFF MECHANISM

The FIT was introduced on 1st April 2010 across GB.[18] The scheme was originally intended *'to encourage deployment of additional small scale low carbon electricity generation, particularly by individuals, householders, organisations, businesses and communities who have not traditionally engaged in the electricity market*' (DECC, 2010a p. 6). It works alongside the RO, which remains the central mechanism for supporting large-scale renewables. The tariffs are banded by technology type and scale and the scheme consists of two elements of payment for generators. It is a fixed price model with a set generation tariff paid for every kWh of electricity generated and metered by a generator, whether used onsite or exported. In addition an export tariff is paid so generators can receive a guaranteed market and price for exported electricity. This was initially set at 3p/kWh exported and is now 4.5p/kWh, but generators can choose to opt out of this and sell their electricity on the open market or through negotiated PPAs.

The FIT applies to renewable installations with a maximum capacity of 5 MW and includes anaerobic digestion (AD), hydro, solar photovoltaic (PV) and wind projects up to that limit (see Table 2). It also includes a pilot programme to support the first 30,000 micro CHP installations with an electrical capacity of 2 kW or less, although these are not analysed in this thesis for reasons explained in Chapter 1. The FIT rates are set with consideration of technology costs and electricity generation expectations at the various different scales.

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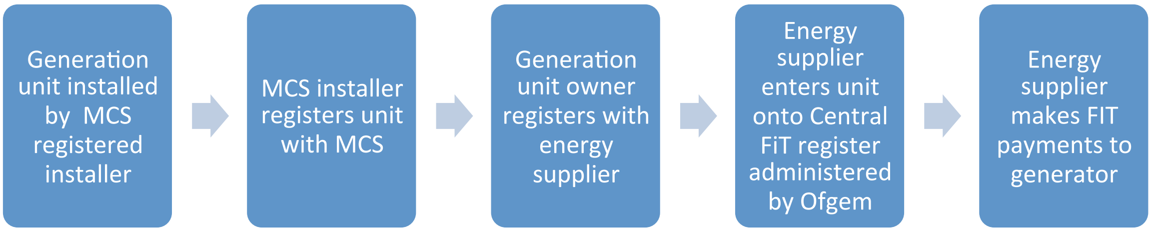
[18] The FIT scheme applies across England, Scotland and Wales. Northern Ireland has separate legislation.

Initially they were set to deliver an approximate rate of return of 5-8%, linked to the Retail Price Index (RPI), for a total of 20 years for AD, hydro and wind, and 25 years for PV. The rates were planned to degress each year for new installations to reflect the predicted cost reductions as technologies mature, and to encourage and drive decreases in installation costs. Degression was planned to start in April 2012 to give technology supply chain industries a stable period in which to establish.

The scheme is administered by Ofgem who maintain a Central FIT Register of all FIT installations. Ofgem also accredit all wind and solar PV projects over 50kW and all hydro and AD installations under the ROO-FIT process. Any wind or solar installations under 50KW must use Microgeneration Certification Scheme (MCS) eligible products installed by MCS accredited installers.[19] After installation the only interface that generators have with the scheme is through a licensed electricity supplier (the FIT Licensee[20]) who makes the FIT payments. Those payments derive from a levy placed on electricity bills by suppliers. The FIT process is shown in Figure 5.1 below.

FIGURE 5.1 THE FIT PROCESS FOR WIND AND SOLAR PV INSTALLATIONS UNDER 50KW



Adapted from DECC (2012f).

The initial tariffs are shown in Table 5.2 below.

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[19] The MCS is an independent industry-led certification scheme accredited by the UK Accreditation Service, which assesses installer companies and products against set standards.

[20] As of October 2012 there were 15 FIT Licensees. 6 of these are Mandatory FIT licensees, meaning they are obliged to provide FIT payments and administration as part of their licence conditions if they have over 250,000 customers.

TABLE 5.2 THE INITIAL FIT GENERATION TARIFF BY TECHNOLOGY

Technology	Scale	Tariff level for new installations (p/kWh)	Tariff Lifetime
		Year 1: 1/4/10 – 31/3/11	
Anaerobic digestion	≤500kW	11.5	**20**
Anaerobic digestion	>500kW	9.0	**20**
Hydro	≤15kW	19.9	**20**
Hydro	>15-100kW	17.8	**20**
Hydro	>100kW-2MW	11.0	**20**
Hydro	>2MW – 5MW	4.5	**20**
MicroCHP Pilot	<2kW	10	**10**
PV	≤4kW (new build)	36.1	**25**
PV	≤4kW (retrofit)	41.3	**25**
PV	>4-10 kW	36.1	**25**
PV	>10-100kW	31.4	**25**
PV	>100kW – 5MW	29.3	**25**
PV	Stand alone system	29.3	**25**
Wind	≤1.5kW	34.5	**20**
Wind	>1.5-15kW	26.7	**20**
Wind	>15-100kW	24.1	**20**
Wind	>100-500kW	18.8	**20**
Wind	500kW-1.5MW	9.4	**20**
Wind	>1.5MW-5MW	4.5	**20**
Existing microgenerators transferred from the RO		**9.0**	**To 2027**

(Source: DECC, 2010a)

SECTION 5.8 CHANGES TO THE FEED-IN TARIFF

The scheme has undergone a number of changes with a total of five consultations since it was introduced. This includes changes to the budget, a fast-track review, the closure of a loophole, and a comprehensive review in two phases; this section outlines and explains those developments. This is important to illustrate because the number of changes, and the way in which they have been introduced has had a considerable impact on the FIT and the sector that works with it. It has also had ramifications outside of the small-scale RE sector, as will be discussed in Chapter 6, and it is therefore necessary to explain what has occurred and when.

SECTION 5.8.1 BUDGET

Following the Treasury's Spending Review in October 2010 DECC now have a Control Framework for levy-funded spending (HM Treasury, 2010; DECC, 2011). This limits the amount of money that can be raised by levy for DECC's programmes. Included within the framework are the RO, the Warm Home Discount[21] and FITs. This effectively placed a cap on the FIT budget which was initially set at £867 million and later increased to £1,064 million. A cap was not built into the original modelling.

This cap is a significant change in the design of the scheme because it has moved it away from a basic FIT design where a price is set for generated power and the market is allowed to respond with the capacity, with controls occurring only through pre-planned degression. A basic FIT design removes any volume, or 'cliff-edge' risk that support will be removed beyond a certain capacity. But it introduces greater policy risk because the level of intervention, and therefore the potential for change, is greater. By introducing a cap, the FIT is now a hybrid scheme where DECC are attempting to set the price of power *and,* effectively, control the total volume. This approach results in the policy risk implicit in Government set tariffs but also the volume risk if the scheme is too successful. As with any infrastructure project, if the risk profile increases so does the cost of capital and ultimately the costs of delivering the scheme.

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[21] The Warm Home Discount scheme is a four-year scheme that runs from April 2011 to March 2015 to provide rebates and discounted tariffs for energy costs in low-income and vulnerable households.

The introduction of a cap on FIT spending, and higher than expected installation rates for solar PV, have led to a number of regulatory changes in quick succession as DECC have sought to control the scheme.

SECTION 5.8.2 FAST-TRACK REVIEW

The first review of the FIT was announced on 7 February 2011 with the consultation running from 18 March to 6 May. It was a fast-track review for solar PV over 50kW, the threshold used in the statutory definition of microgeneration. It was a response to the perceived interest in large-scale solar projects. It stated -

> *'Large scale solar PV could potentially divert funding away from community and domestic installations that better meet the objectives of the FITs scheme…The analysis undertaken prior to the start of the FITs scheme projected that the vast majority of PV incentivised by FITs would be at the domestic or small scale and did not predict any solar PV above 10kW in the early years of the scheme and failed to take account of the impact on returns of debt finance available to sophisticated investors* (DECC, 2011, p.9/10).

It argued that the justification for the high levels of support required for solar PV came from its potential role in engaging the general public in low carbon electricity generation. It suggested that -

> '*These benefits are most evident at the domestic and community scale and generally become less discernible as installations become larger, more commercial and more remote from individuals and communities*' (DECC, 2011, p.15).

It proposed three new tariff bands for solar PV and a reduction in tariff rates for everything over 50kW. The new tariffs, with effect from 1 August 2011, were –

• **>50kW – 150kW**	• **19.0p/kWh**
• **>150kW – 250kW**	• 15.0p/kWh
• **>250kW – 5MW and stand-alone installations**	• 8.5p/kWh

The review also raised the tariff for AD which had so far resulted in just two installations. The AD tariff was raised to 13p/kWh for 250kW – 500kW and to 14p/kWh for <250kW. The tariff above 50kW was left at 9p/kWh.

SECTION 5.8.3 CLOSURE OF THE SOLAR PV EXTENSION LOOPHOLE

After the fast-track review was announced DECC became aware of a number of developers who were intending to exploit a loophole within the FIT legislation. The loophole would allow a developer of a project with an eligibility date before the 1 August cut-off to extend the capacity to the maximum 5 MW within 12 months and still be eligible for the pre-1 August tariff for the extended installation. In effect, developers could benefit from the original tariffs after the scheme was reviewed. Due to the speed with which the fast-track changes came into force, many developers were exploring this option because they could not complete their installations in time.

DECC closed this loophole with a consultation which ran from 27 July to 31 August 2011 and came into force on 18 October 2011.

SECTION 5.8.4 COMPREHENSIVE REVIEW PHASE 1

On 7 February when the fast-track review was announced DECC also stated an intention to undertake a Comprehensive Review of the FIT in order to improve its efficiency. The review considered all aspects of the scheme including -

- tariff levels;
- degression rates and methods;
- eligible technologies;
- arrangements for exports;
- administrative and regulatory arrangements;

- interaction with other policies;
- accreditation and certification issues (DECC, 2011g).

The review was carried out in two phases. Phase 1 was focused on support for solar PV and a consultation ran from 31 October to 23 December 2011. The review made three key changes – it reduced all tariffs under 250kW (see table 5.3), it linked those tariffs with minimum energy efficiency requirements, and it introduced new multi-installation tariff rates for aggregated solar PV schemes, all explained below (DECC, 2011c).

TABLE 5.3 TARIFFS FOR SOLAR PV FOLLOWING COMPREHENSIVE REVIEW PHASE 1

Band (kW)	**Original generation tariff (p/kWh)**	**Generation tariff from 1 April 2012 (p/kWh)**	**Multi-installation generation tariff (p/kWh)**
≤4kW (new build)	37.8	21.0	16.8
≤4kW (retrofit)	43.3	21.0	16.8
>4-10kW	37.8	16.8	13.4
>10-50kW	32.9	15.2	12.2
>50-100kW	19	12.9	10.3
>100-150kW	19	12.9	10.3
>150-250kW	15	12.9	10.3
>250kW-5MW	8.5	8.9	8.9
stand alone	8.5	8.9	8.9

Source: DECC, 2011g

These changes were intended to bring the tariffs back in line with the decreased costs of solar PV (discussed in Chapter 6 and Chapter 7) and to provide the 5% rate of return that the scheme was originally designed to deliver. The one exception to this rate is for sub 4kW installations which are designed to deliver 4.5% rate of return due to the changed investment environment since the FIT was introduced. The new tariffs were intended to apply from 1 April 2012 to installations with an 'eligibility date'[22] on or after a 'reference date'[23] which was first proposed as 12 December 2011. This reference date was six weeks after the consultation was released but two weeks before it closed. DECC considered that '*the immediacy and extent of the risk of breaching the spending envelope (for FITs) makes it necessary for tariff changes to be implemented rapidly.*' This rapidity was a very contentious issue which disrupted the solar PV sector and caused difficulties for all stakeholders concerned (EAC and ECCC, 2011).

A Judicial Review was filed against DECC in relation to their proposal to reduce tariffs from a reference date prior to the completion of the consultation period. It was launched by Solar Century Holdings Ltd, Friends of the Earth and Homesun. The High Court ruled the Comprehensive Review approach unlawful and the Court of Appeal subsequently upheld the ruling. DECC then appealed to the Supreme Court against the Court of Appeals' decision but again the ruling was upheld. As a precaution, during the court proceedings DECC proposed a second reference date for 3 March 2012 which would be used if the ruling stood.

This created uncertainty for the sector and potential generators because it was unclear what tariff a generator would receive if the installation eligibility date was between 12 December 2011 and 3 March 2012. If DECC's process was upheld as unlawful then the generator would have received 43.3p/kWh for 25 years. If the ruling was overturned the generator would receive 43.3p/kWh until 1 April 2012 and then 21p/kWh for the remainder of the 25 years. Over the lifetime of the tariff for a 3kW system this represents the difference between approximately £25,980 total income from the original generation tariff or £12,600 from the new reviewed tariffs.[24] This made it very difficult for the solar industry to sell PV systems while the court case continued. But the result meant that any installation fitted before 3 March 2012 did receive the initial 43.3p tariff for the full 25 years. This also had implications for the installation rate of solar PV which is discussed in Section 6.3.1.

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[22] Eligibility date means the date from which an installations eligibility for FIT payments commences (DECC, 2011g)

[23] The reference date is the date after which new installations would receive the reduced tariff from 1 April 2012.

[24] This calculation assumes an average yield from a 1kW peak solar PV module of 800kWh/year. It is a basic estimation that does not include uprating. It is used here to illustrate the degree of difference between the two tariffs.

The review also introduced a requirement that after 1 April 2012 installations would only be eligible for the full FIT rates if the building to which the installation is attached has an energy performance certificate (EPC)[25] rating of D or above. 51% of dwellings are rated at this level currently and 65% of non-domestic buildings meet it (DECC, 2012b). Energy efficiency measures could include cavity wall and loft insulation, heating controls, hot water cylinder insulation, and installation of a replacement boiler. The costs vary by property but are approximately £530 - £1280 for most properties. This is a significant impact on the economics of solar PV representing approximately 5–10% of the total capex. The Impact Assessment accompanying the review estimates that the dampening effect on demand for solar PV is 40% in 2012/13, 25% in 2013/14 and none in 2015/16. This reflects the general improvement of the UK housing stock over the period and the relative ease of meeting EPC level D for most properties (DECC, 2012m).

The new multi-installation tariff rates introduced with the review were set at 80% of the standard tariffs to reflect the economies of scale associated with aggregated projects. Including the reviewed standard tariffs, this change represented a 61% reduction in tariffs for sub 4kW retrofit installations, which were the predominant focus of the aggregated schemes. This is a very significant reduction in the available returns for aggregated schemes, as were the reductions for all solar PV installations. The degree and pace of change required of the solar PV sector resulted in many installers going out of business. This is discussed further in Chapter 7. But the changes to the FIT have also impacted on the wider electricity regime in terms of the perception of policy risk. This is discussed further in Chapter 8.

SECTION 5.8.5 COMPREHENSIVE REVIEW PHASE 2A

DECC split Phase 2 of the Comprehensive Review into two parts. 2A dealt with the cost control of solar PV (this section) and 2B dealt with the tariffs for non-PV technologies and scheme administration issues (section 5.8.6).

Phase 2A introduced a further reduction in the solar tariff to 16p/kWh for domestic installations from 1 August 2012, which was a response to a continued fall in module prices.

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[25] All homes bought, sold or rented require an EPC. It carries a rating that compares current energy efficiency and carbon emissions with potential figures that the property could achieve.

It also increased the multi-installation/aggregated solar PV tariff to 90% of the standard rate, rather than the 80% introduced in the Fast-track review in response to an updated consultancy report stating that only 10% reductions were possible. The new tariffs are shown below.

TABLE 5.4 GENERATION TARIFFS FOR NEW SOLAR PV INSTALLATIONS FROM 1 AUGUST 2012

Band (kW)	Standard generation tariff (p/kWh)	Multi-installation tariff (p/kWh)	Tariff received if EPC D rating not met (p/kWh)
≤4kW (new build)	16.0	14.4	7.1
≤4kW (retrofit)	16.0	14.4	7.1
>4-10kW	14.5	13.05	7.1
>10-50kW	13.5	12.15	7.1
>50-100kW	11.5	10.35	7.1
>100-150kW	11.5	10.35	7.1
>150-250kW	11.0	9.9	7.1
>250kW-5MW	7.1	N/A	N/A
stand alone	7.1	N/A	N/A

Source: DECC, 2012a

Phase 2A also reduced the support period for solar PV from 25 to 20 years and it increased the export tariff from 3p/kWh to 4.5p/kWh for installations with an eligibility date on or after 1 August 2012.

The review also considered the degression mechanism that had been built into the original FIT design. Initially, the rates of return and the tariff levels were to be reviewed annually after an initial three-year period in which the scheme would be left alone. However, as DECC have since stated,

'Deployment of Solar PV depends on many factors including installation costs, investor hurdle rates, non-FITs revenue like bill savings, and wider economic considerations such as disposable income, cost of capital, and alternative investment opportunities. Some of these factors are challenging to estimate today and even more difficult to forecast into the

future. In addition, some of these factors, especially costs, are very sensitive to market conditions and can be volatile in the short term' (DECC, 2012a).

The initial design of the FIT did not build in a flexible process that could respond to the volatility of the influencing factors outlined in the quote above. The review and consultation process is relatively slow which has hindered DECC's ability to make timely interventions in the mechanism. It also creates uncertainty within the sector because the points at which DECC felt it needed to review the scheme were not known to industry before they happened.

The result of this inflexibility has been that DECC have been unable to effectively respond to changes in the market, particularly solar PV cost reductions, and this has led to unexpected deployment levels. The only recourse that DECC had was to review the scheme when it perceived deployment to be too high. This is what it has done with a total of five consultations up to 31 August 2012 but it has been criticised for being reactive and not transparent (EAC and ECCC, 2011).

Due to the introduction of a budget to the scheme (see Section 5.8.1), the costs of the FIT must be contained and therefore a more responsive degression mechanism was required. DECC stated -

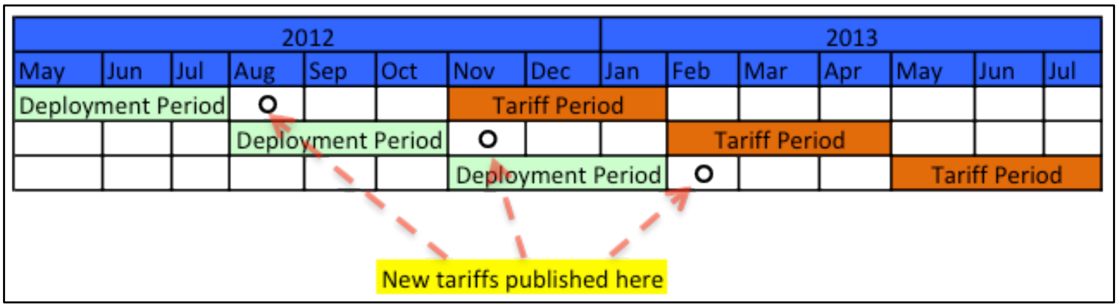
'*The pace of change in the solar PV market has also exposed the limitations of the Feed-in Tariff scheme in its original form. In particular, it has highlighted the need to find a new way to enable solar PV tariffs to respond more nimbly to market developments*' (DECC, 2012a, p.3).

In the consultation document DECC put several degression options forward -

1. *Pre-planned degression,* where tariffs are adjusted according to a pre-set deployment level;
2. *Contingent degression,* where tariffs are adjusted automatically, though with time lags, in response to deployment levels or other triggers such as expenditure;
3. *More frequent reviews* of tariffs;
4. *Rationing/quotas,* where there is a fixed allocation of new capacity or funding allocated each year.

The contingent degression model (2) was selected and took effect from 1st November 2012. It effectively introduces more frequent, and fixed, tariff changes every three months that have a reduction between a baseline of 3.5% up to a potential 28% depending on deployment levels. As illustrated in Figure 5.2 below, tariff setting is *contingent* on the deployment levels over the 3-month period (Deployment Period) that occurred 3 months prior to the period in which the tariffs stand (Tariff Period). The tariffs to be introduced in the Tariff Period are published by Ofgem the month after the Deployment Period leaving over 2 months for the industry to prepare. If deployment has been extremely low then a tariff cut can be skipped for a maximum of two successive degressions (DECC, 2012a).

FIGURE 5.2 ILLUSTRATION OF THE CONTINGENT DEGRESSION MODEL



Adapted from Candelise and Gross (2012)

The contingent degression model is a far more transparent system than the FIT in its original design because it gives the industry over 2 months notice of any change and provides certainty over Government thinking. This provides greater security to investors, developers and generators than under annual or sporadic reviews, as occurred before the contingent degression framework was introduced (Couture et al. 2010). It also allows for a higher degree of control over the total costs of the scheme which was a central driver for DECC introducing it. However, it does also entail a higher administrative burden for Ofgem who must closely monitor the scheme and set tariff levels accordingly every 3 months.

Finally, the Comprehensive Review Phase 2A created three new bands of solar PV support – domestic (0 – 10kW), small commercial (10 – 50kW) and large commercial/utility (over 50kW and stand-alone) (DECC, 2012a). This was introduced because each of those bands represents a distinct market segment that is subject to specific cost reductions. By treating them separately DECC intend to be able to respond to developments in different areas of the market.

SECTION 5.8.6 THE COMPREHENSIVE REVIEW PHASE 2B

Phase 2B made some minor adjustments to the tariffs for non-PV technologies and addressed some scheme administration issues. There were three key changes –

1. Degression of the non-PV tariffs will begin in April 2014 with a baseline annual reduction of 5% but with provision up to 20% in cases of high deployment. Degression above the baseline will be triggered by capacity limits being reached.
2. It will be possible for developers of all hydro and AD schemes, and wind and solar schemes over 50kW, to receive Preliminary Accreditation. This is a system, present within the RO, which fixes the tariff rate an installation will receive for 6 months to two years while it is being developed. To receive this guarantee a developer must have received planning approval, have evidence of a firm grid connection offer and have acquired any environmental approvals. This is a potentially important development for all schemes with long lead times that have previously faced problems raising development finance due to uncertainty over future revenue. However there may still be an issue for developers in getting projects to the stage that they are eligible for Preliminary Accreditation. For example, getting planning approval and environmental licenses for a hydro scheme can take up to 2 years (see Chapter 6 Section 6.3.2). However, in tandem with the more transparent degression system, this development may provide greater security for developers.
3. Community groups have received a status that is distinct from other projects. This entitles them to exemptions from the EPC requirement for solar PV installations and also gives access to Preliminary Accreditation rights for solar PV projects under 50kW. This is in recognition of the longer period required to set up a community-owned aggregated PV scheme.

SECTION 5.8.7 THE CHANGING OBJECTIVES OF THE FIT

A requirement of effective policy-making is outlining the objectives that the policy is designed to achieve (Hamilton, 2006). This allows Government to be able to measure the success of the policy and it gives an indication of what the underlying drivers are for Government. The Green Book, which guides public sector policy-making and evaluation (see Chapter 1 Section 1.7), states that -

'*If an intervention seems worthwhile, then the objectives of the proposed new policy, programme or project need to be stated clearly…Objectives should be stated so that it is clear what proposals are intended to achieve*' (HM Treasury, 2003, p.13).

The FIT has had many objectives associated with it and it is argued here that this has been problematic in working with, and evaluating, the scheme. As is explained below, not all impacts of a policy can be quantified – for example, awareness of energy issues – but this does not mean that benefits do not arrive. The difficulty of qualitative versus quantitative accounting has meant that non-quantifiable benefits and disbenefits have not always been recognised. This thesis attempts to incorporate these aspects of the FIT, both positive and negative.

The headline objective of the FIT on introduction was *'to encourage deployment of additional small scale low carbon electricity generation, particularly by individuals, householders, organisations, businesses and communities who have not traditionally engaged in the electricity market*' (DECC, 2010a). This can be split into two central objectives of the scheme which were deployment of small-scale RE and new market entry.

However, the Impact Assessment released at the introduction of the FIT expanded on this with a wide-range of other objectives outlined in just four paragraphs. These included -

1. Help to meet the 2020 RE target and the UK's carbon reduction targets;
2. Public engagement in electricity;
3. Behavioural change in terms of energy use;
4. Acceptance of the need for RE development;
5. Diversifying the energy mix;
6. Reduce dependence on fossil fuels;
7. Greater energy security at the small scale;
8. Business and employment opportunities in developing and deploying RE technologies;

9. Avoidance of losses through transmission and distribution networks;
10. Encouraging supply chains and economies of scale to develop;
11. Reduce the costs and competitiveness of small-scale RE technologies.

(DECC, 2010b, p. 8-9).

Initially the number and variety of these objectives was useful in gaining acceptance for the scheme. Many of this study's interviewees suggested that one of the reasons the FIT was introduced was because different actors were able to hang their own narrative from it. Within Parliament the Conservatives were able to fit it into the Localism agenda and the broad belief in the power of the individual, for the Labour Party it chimed with their communitarian agenda, and for the Liberal Democrats, whose power base is traditionally within local government, any policy that decentralises power is to their benefit. Equally within industry a diversity of objectives and motivations were expressed in relation to the FIT (Interviews 10, 4, 7, 16).

However, it is argued here that this diversity has also created problems in evaluating the scheme. It is difficult to prove that a policy with many different outputs is being effective, particularly if those outputs are intangible, such as behavioural effects or consumer engagement. Policy-making that creates externalities, even if those externalities are positive (e.g. the strengthening of communities around an RE development supported by a policy mechanism) is open to criticism because it cannot verify its own success (Interview 16). This has become increasingly problematic as the scheme has continued and the impacts have become more diverse. One of the contributions that this research makes to the understanding of the FIT scheme is to highlight those externalities and assess what role they have had in the wider process of transition in the electricity system.

An additional difficulty with a policy mechanism with multiple objectives is that the risk of investing on the back of the scheme increases because investors are unsure as to where the Government's central motivations lie. This is important because when a scheme is reviewed, as the FIT has been several times, changes are made that align the scheme with the Government's intentions but may negatively impact investors (e.g. large-scale solar PV support cut in the fast-track review). The result is a very political environment in which to invest and develop which has an associated risk premium (Interview 28). Hamilton (2006), in evaluating investment risk associated with the RO, argued that -

'Another general point is clarity on the underlying objective of renewables policy…Unsurprisingly, at a point of review or change, investors want to understand what are the fundamentals that are driving policy, how will it evolve, what is government committed to achieving: is it about carbon longer term; about simply meeting targeted volumes whatever technology is used; about diversity of supply options and 'bringing forward' new technologies? This would also be relevant for energy policy more generally: conflicting objectives increase risk or delay investment as it leaves the investor to 'guess' where the priority lies or waiting for one of the 'pieces' to be further defined' (Hamilton, 2006, p.12).

This need for clarity became clear to Government as they received criticism over the FIT scheme - *'A recurring theme in feedback received during the course of the comprehensive review has been that greater clarity is needed on the aims of the FITs scheme'* (DECC, 2011g, p.9). Also the number and variety of objectives associated with the FIT came under closer Government scrutiny as the Coalition Government introduced a budget-cap and the cost of solar PV installations rapidly decreased (see Chapter 6 Section 6.3.1).

DECC attempted to gain control of the scheme by revisiting and clarifying the objectives in the Comprehensive Review Phase 1 (DECC, 2011g). The focus shifted from deployment and new entry, with a host of secondary objectives (outlined above), to include a caveat that the scheme '*must be affordable in the context of the control framework for DECC levy-funded spending and provide value for money to consumers'* (DECC, 2011g, p.8). The review stated that three wider aims of the FIT justified its expense over the cost of offshore wind, the '*marginal cost effective technology required to deliver the UK's 15% renewable target'* (DECC, 2011g, p.9). These were –

1. Empowering people and giving them a direct stake in the transition to a low- carbon economy;
2. Helping develop a supply chain that offers households a wide range of cost effective measures to lower their energy use and carbon emissions; and

3. Assisting in public take-up of carbon reduction measures, particularly measures to improve the energy efficiency of buildings.

As explained in Section 5.8.4 energy efficiency requirements were attached to the FIT in the Comprehensive Review Phase 1, which is a response to these new objectives for the scheme. It became a requirement that after 1 April 2012 installations would only be eligible for the full FIT rates if the building to which the installation is attached has an EPC rating of D or above. The review stated that the linking of energy efficiency with the FIT was a result of the Coalition view *'that energy efficiency should always be the first step for those considering how to improve the energy performance of their buildings, particularly as energy efficiency measures, in terms of cost per tonne of carbon dioxide emissions saved, are a more cost effective way of cutting carbon than on-site electricity generation'* (DECC, 2011g, p.24). Although it is not stated in any Government documents, it may also be the case that the EPC prerequisite was introduced because it would slow down the deployment rate of solar PV by driving up the costs of installation for the 49% of domestic properties that were without EPC ratings of D or above on 1 April 2012.

However, whatever the motivation for introducing energy efficiency requirements, the objectives have been made clearer and have also reduced in number. It would be very difficult for one policy mechanism to achieve all of the objectives initially outlined when the FIT was introduced. Even if they were achieved it would be difficult to evaluate changes in areas such as behaviour change or to associate those changes with the FIT in isolation.

The FIT has undergone many changes since its introduction as section 5.8 has shown. These changes have developed the scheme into a more transparent mechanism but it is also more tightly controlled and it is becoming increasingly complex. One of the motivations for the introduction of the scheme was to counter the complexity of the RO and the impact this had on shutting-out new entrants to the electricity sector. It is yet to be seen how the sector, and new entrants, respond to the increasing refinement of the FIT.

SECTION 5.9 CHAPTER SUMMARY

This chapter has explored the development of RE policy in the UK in order to give the background to the introduction of the FIT, and the key design elements and changes that have occurred. It started by explaining that the NFFO and the RO were designed to deliver low-cost RE capacity and the majority of the technologies that are supported under these schemes are large scale, mature technologies owned by a small number of companies. Also, because the RO is a complex and risky mechanism it is difficult for small-scale, and independent actors to engage with and therefore the amount of small-scale RE capacity it has delivered is low. This thesis argues that the deployment of small-scale RE could deliver a number of benefits including the introduction of new market entrants which could mobilise new pools of investment, increase the number of beneficiaries in the electricity system, and improve buy-in to system transition and acceptance of change. It is suggested that small-scale technologies therefore require specific policy support that has not been provided by the NFFO or the RO.

The chapter argued that the microgeneration grant schemes that existed before the FIT were inconsistent and did not provide the support required to develop a sector. But FIT mechanisms have been introduced in many countries because they remove some of the key risks for small-scale generators. In providing a guaranteed price and buyer for power, FITs *can* partly insulate small-scale projects from the electricity market and provide a secure and certain platform for investment. The rest of this thesis will evaluate how successful the GB FIT has been at insulating solar PV, wind, hydro and AD generators and it will explore how this has impacted on the process of transition in the electricity system.

The second half of this chapter has outlined the design of the GB FIT and explained how the mechanism has been reviewed and changed. This background is important for understanding the analysis and discussion in the remaining chapters. The FIT exists within a historical, and a current, context that affects the way in which it is managed, perceived and employed. The installation numbers and deployment trends are also largely a result of the design of the scheme and the way in which it has been managed. The next chapter discusses this in detail.

Chapter 6 Installation Numbers and Trends under the GB Feed-in Tariff

SECTION 6.1 CHAPTER INTRODUCTION

This chapter has two main sections. Section 6.2 outlines the headline figures and deployment trends for the FIT since its introduction up to 31 August 2012. Section 6.3 explores each FIT-technology in turn. It shows the installation rate and introduces some of the central factors affecting deployment for each technology. This chapter directly answers Secondary Research Question 1 –

- What are the trends in deployment for each of the four renewable technologies supported by the FIT?

SECTION 6.2 HEADLINE FIGURES FOR THE FEED-IN TARIFF

The GB FIT supported a combined installed capacity of 1.4GW covering 315,424 installations as of 31 August 2012. 15.6MW of capacity has 'migrated' from the RO covering 3673 installations[26], meaning that the FIT brought forward 311,751 installations in two years and 5 months. Solar PV represented 90.8 per cent (1.3GW) of the total installed capacity, and 98.7 per cent (311,460) of all installations (DECC, 2012g). In total there are 216, 021 generators supported under the scheme. These figures are shown in Table 6.1 below.

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[26] On introduction of the FIT, some existing generators who were receiving support under the RO had the option to 'migrate' to the FIT. Eligibility was dependant on the technology type, scale and date of installation.

TABLE 6.1 FIT INSTALLATIONS AND CAPACITY (KW) BY TECHNOLOGY

Technology	**Pre-FIT installed capacity[27] (kW)**	**Cumulative installed capacity (kW) 31 August 2012**	**Cumulative installed capacity (kW) 31 August 2012 - % of total**
Anaerobic digestion	0	20,270	1.4%
Hydro	1700	28,498	2.0%
MicroCHP pilot	0	400	0.0%
Solar PV	7800	1,272,586	90.8%
Wind	5000	79,972	5.7%
TOTAL	**14,500**	**1,401,746**	-
Of which domestic	-	986,565	70.3%
Of which non-domestic	-	415,160	29.6%
Technology	**Pre-FIT number of installations**	**Cumulative number of installations August 2012**	**Cumulative number of installations August 2012 - %**
Anaerobic digestion	0	23	>0.1%
Hydro	122	324	0.1%
MicroCHP pilot	0	393	0.1%
Solar PV	2811	311,460	98.7%
Wind	740	3,224	1.0%
TOTAL	**3673**	**315,424**	-
Of which domestic	-	305,296	96.8%
Of which non-domestic	-	10,128	3.2%

Source: DECC, 2012e and DECC, 2012g

The two most striking trends in these figures are the high number of installations and the dominance of solar PV as a technology choice. 3673 installations under 5MW in all technologies combined were migrated from the RO. 315,424 installations is a huge increase within a short period and by this measure, the FIT has been a very successful mechanism. But 98.7% of installations have been solar PV and the other technologies have achieved only very modest increases. Section 6.3 explores each technology in more detail to illustrate why this has occurred.

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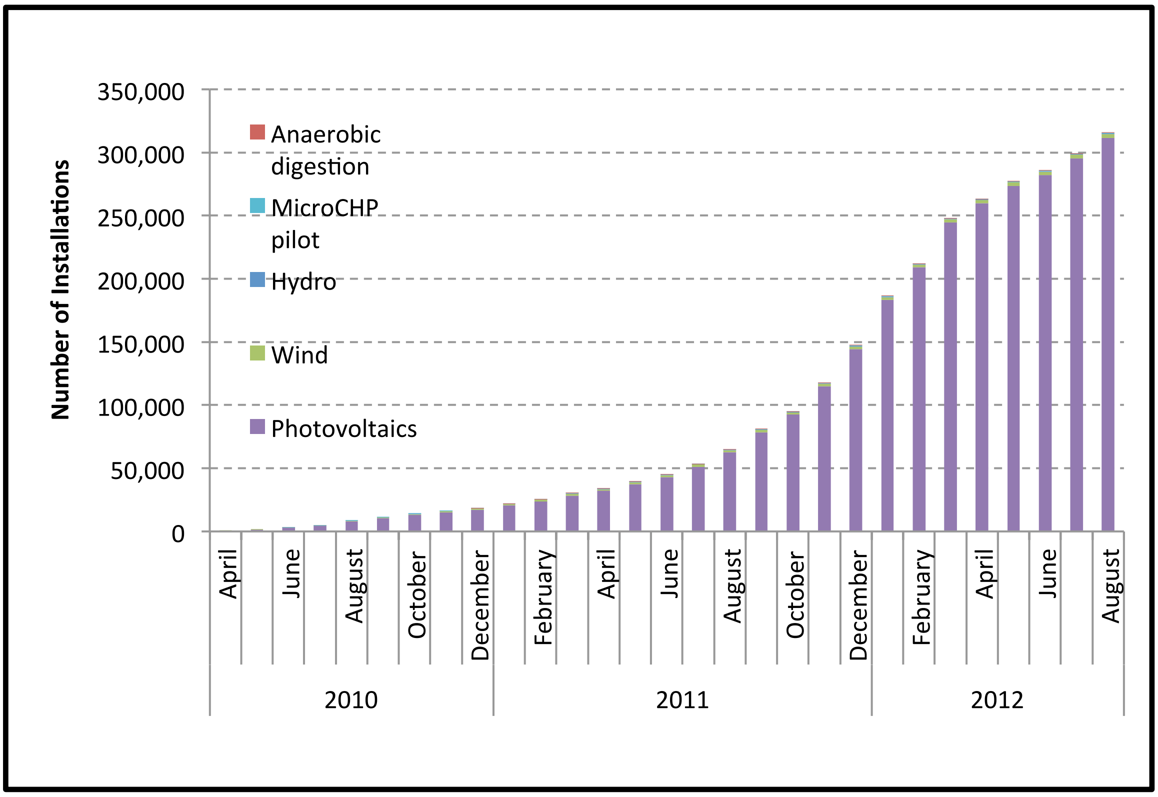
[27] This is the number of installations that have migrated from the RO.

FIGURE 6.1 CUMULATIVE INSTALLATIONS CONFIRMED IN FITS AT END OF AUGUST 2012



Source: DECC (2012g)

Figure 6.1 shows the sharp increase in FIT installation rates between July 2011 and March 2012. The timing of this is mostly explained by two key developments –

1. A number of factors coincided to drastically cut the price, and raise the returns, of solar PV installations;
2. Demand for solar PV installations boomed in response to announced changes to the tariff rates.

But the picture of solar PV development under the FIT is complex and involves many interrelating factors. These are discussed in Section 6.3 and Chapter 7.

Figure 6.1 also illustrates the dominance of solar PV (in purple) over the other four technologies. DECC did anticipate that solar PV would be the biggest beneficiary from the FIT, projecting that up to 2020 it would account for over 90% of installations, around 70% of FIT costs to consumers, and 60% of total electricity output under FITs (DECC, 2012g). But by mid-2012 solar PV had almost three times the modelled deployment whilst hydro had delivered the predicted deployment and AD and wind had delivered less than expected.[28]

All RE projects have a number of barriers and risks to their development. Support mechanisms typically help in one or more of the following ways; they can help lower the cost of investment, they can increase the potential return compared to investment in other energy projects, or they can decrease the associated project risks. The FIT increases, stabilises and guarantees the return on investment, which for solar PV projects at all scales is the most significant factor. As will be discussed in Chapter 9, other technologies have additional risks that slow the rate of deployment. For solar PV supported under the FIT, natural brakes such as gaining planning permission, installation time, licensing delay, and securing feedstock contracts (for AD) do either not exist or are less significant. Thus for solar PV, the FIT revenue facilitated a very rapid rate of deployment.

The following section provides a technology-by-technology summary, explaining why this has occurred in more detail. It provides a closer analysis of the installation numbers for each technology and explains some of the important factors explaining the trends in deployment. The developments relating to the costs of technologies are introduced in this section but Chapter 7 Section 7.4 addresses costs in greater depth.

SECTION 6.3 TECHNOLOGY SUMMARIES

SECTION 6.3.1 SOLAR PV SUMMARY

Solar PV has been the dominant technology receiving support from the FIT and the high level figures suggest the scheme has been very successful. It accounts for 99% of installations but only 91% of capacity due to the high percentage of small, mostly sub 4kW, systems. Of the total number of supported solar PV installations 292,926, or 97%, were domestic schemes and 305,296, or 94%, were sub-4 kW. This trend towards small domestic

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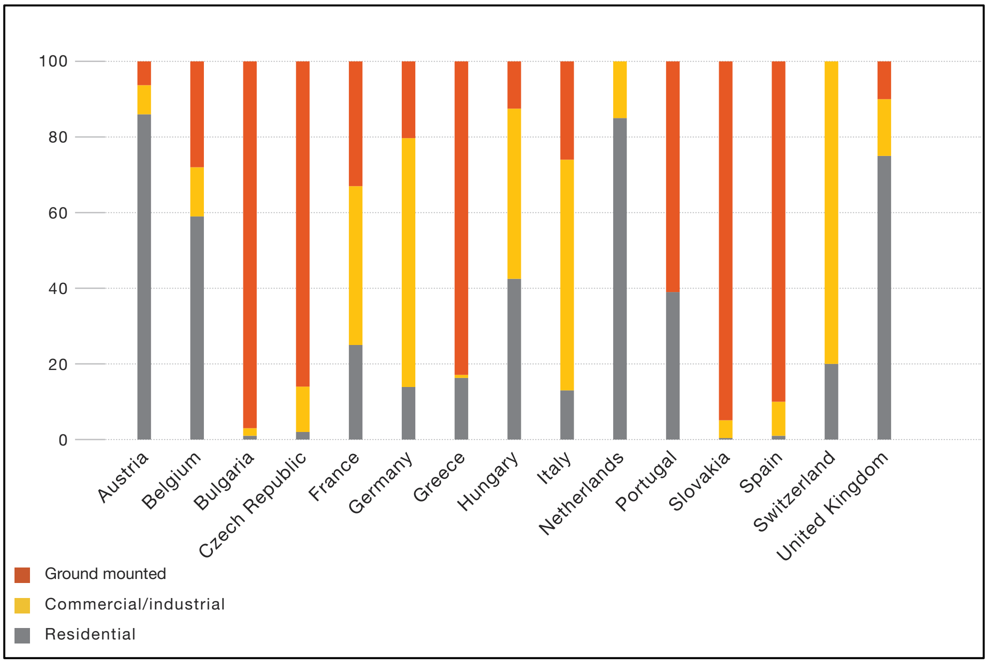
[28] The original modelling figures were shown to the author in an interview with an official at DECC.

schemes is unusual within Europe where there is a high penetration of commercial schemes. The installed capacity of each installation type is shown in Figure 6.2 below.

FIGURE 6.2 SOLAR PV INSTALLATION TYPE AS A PERCENTAGE OF CAPACITY BY EUROPEAN COUNTRY



Source: EPIA, 2012

SECTION 6.3.1.1 DOMESTIC SOLAR PV PREFERENCE

Domestic solar PV was always intended to be the main beneficiary of the GB FIT because it is seen to '*meet the objectives of the FITs scheme, which are to drive uptake of a range of small-scale low carbon electricity technologies by* ***non-energy professionals*** *in order to deliver a higher rate of deployment; and to pursue broader aims of* ***engaging the general public*** *in a decentralised low carbon energy economy*' (DECC, 2011e [Author's emphasis]). The tariff levels have reflected this intention in the UK whereas many European countries have encouraged commercial rooftop installations through tariff setting due to a greater emphasis on the capacity additions that solar PV can provide. These are distinct approaches and the industry that develops under each model is quite different. In the UK, a large domestic sub 4kW market has developed and the solar sector is largely geared towards this (DECC, 2012d).

6.3.1.2 AGGREGATED SOLAR PV SCHEMES

Domestic schemes are inherently fragmented because each installation is on an individual roof requiring separate contracts and sales. A development within the UK that has sought to address this issue is the growth in aggregated schemes. There are a number of different aggregation models (discussed in Chapter 7 Section 7.3.2) but the principle is for one central company or organisation to own multiple schemes on multiple rooves. This often occurs within a localised area, allowing the aggregator to achieve economies of scale, and often they retain the income from the FIT and the resident receives the free electricity. DECC state that approximately 20% of solar PV schemes are aggregated (DECC, 2012a). This model of PV installation has allowed aggregators to scale-up their deployment and it is partly responsible for the unexpected levels of installation under the FIT. An example of an aggregated scheme, installed by E.ON in Nottinghamshire, is shown in Figure 6.3 below.

FIGURE 6.3 SOLAR PV ARRAYS ON SOCIAL HOUSING IN ASPLEY, NOTTINGHAM

Source: E.ON Sustainable Energy

SECTION 6.3.1.3 COMMERCIAL SOLAR PV

An unexpected outcome of the FIT was the number of non-domestic PV installations over 4kW. DECC predicted that there would be no installations before 2013 in either a "Small" band of 4 – 10kW or a "Large" band of 10kW – 5MW[29] (DECC, 2011e). As of 31 August 2012 there were 11,370 installations in these two bands. Although this represented just 3.7% of total PV installations the greater size of these installs meant that they represented 31.2% of capacity and therefore a significant part of the costs of the FIT scheme.[30]

SECTION 6.3.1.4 FURTHER REASONS FOR A BOOM IN SOLAR PV INSTALLATIONS

Domestic solar PV is a relatively simple RE installation. It typically has a short sale-cycle, it is a permitted development meaning planning permission is not required in most circumstances, there is low technical risk, and the physical installation is straightforward and quick. This explains why it is a favoured technology but it has exceeded expectations due to a number of additional factors.

1. The primary factor has been a reduction in the capital expenditure (capex) of a PV installation by 49 – 66% since the FIT was introduced (DECC, 2011 and PB, 2012). This is a result of a crash in the silicon, and module, price and an increasingly competitive PV manufacturing sector. This is explained in detail in Chapter 7 Section 7.4.2 but of relevance here is the impact that this capex reduction has had in increasing the returns available under the FIT for solar PV, and consequently the unexpected levels of deployment.

2. Setting tariffs to stimulate renewable technologies is a delicate balancing act between ensuring the support is high enough to mobilise the target investors but also not so high that the market becomes overheated and the mechanism becomes economically inefficient.[31] The approach that DECC took in setting the FIT rates was

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[29] These figures were shown to the author during an interview with an official from DECC.

[30] These figures are correct as of 31 August 2012. The figures used by the EPIA (2012), and illustrated in Figure 6.2, are older and show a slightly lower percentage of solar PV capacity attributed to commercial and ground-mounted schemes.

[31] A support mechanism is considered economically inefficient if it provides a rate of return over the rate required to trigger investment (CEPA and PB, 2011).

based on modelling undertaken by Element Energy and Poyry (Element Energy and Poyry Consulting, 2009). This model assumed that the most technology neutral method for setting tariffs was to base them on a rate of return specific to each technology and scale. It used a range of hurdle rates[32] for large-scale utility and developer investors, and for domestic and commercial investors. It was assumed that investors in large-scale projects had an absolute minimum hurdle rate of 8% rate of return up to 14% for less mature technologies, but that small-scale investors had hurdle rates that ranged from 3 – 20% due to a wider variety of factors informing investment for those actors (e.g. environmental concern, corporate image). The Element Energy and Poyry report thus recommended that the tariffs were based on an 8% rate of return as this would mobilise investment at the small-scale but not the large. The initial tariffs were finally set by DECC to deliver within a range from 5% for PV to 8% for AD for well-sited installations.

3. A CEPA and PB report, which was commissioned by DECC to update the FIT model in October 2011, stated that for domestic and commercial investors in solar PV a 5 – 8% return was too high which was why deployment had been so much higher than the modelled figures. They argued that the vast majority of investors in this grouping who actually had the capital and motivation to invest had far lower hurdle rates, down to 1% (CEPA & PB, 2012). In addition, a proportion of the returns from a FIT supported installation derives from the avoided costs of imported electricity. DECC estimated that by February 2012 electricity prices had increased by an average of 13% since the FIT was introduced (DECC, 2012a). This increased the overall return that an installation will deliver and consequently lowered the hurdle rate for generators further and therefore drove deployment.

4. The CEPA and PB report also showed that commercial developers who were aggregating schemes or investing in larger installations were able to access debt finance that domestic investors typically cannot. This access to debt allows the commercial developers to gear their investment and receive a larger return after

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[32] Hurdle Rate is the minimum acceptable rate of return on an investment for an investor.

gearing is taken into account[33]. They indicated that post tax nominal equity returns of 17 to 22% were possible (CEPA and PB, 2011).

5. In addition, an outcome of the macro-economic conditions since the 2008 banking crisis, has been very low interest rates. This lack of yield elsewhere in the economy stimulated unusual interest in investments that offer a stable low-risk return above the interest rate. Solar PV was increasingly perceived to be a relatively low-risk investment under the FIT. This is because revenue from the FIT is underwritten by Government who represent a low credit risk. Technological and operational risks remain but are relatively low and weather risk is broadly predictable. Consequently, the low risk profile of the technology, coupled with a lack of yield elsewhere, reduced the hurdle rates for investors below DECC's estimates and resulted in higher than expected deployment (CEPA and PB, 2011).

SECTION 6.3.1.5 SOLAR PV INSTALLATION TIMELINE

As stated above, one of the principal reasons explaining the sharp increase in installation rates for solar PV between July 2011 and March 2012 was a boom in demand in response to announced changes to the tariffs. Figure 6.4 below illustrates the degree to which tariff deadlines drove installation rates.

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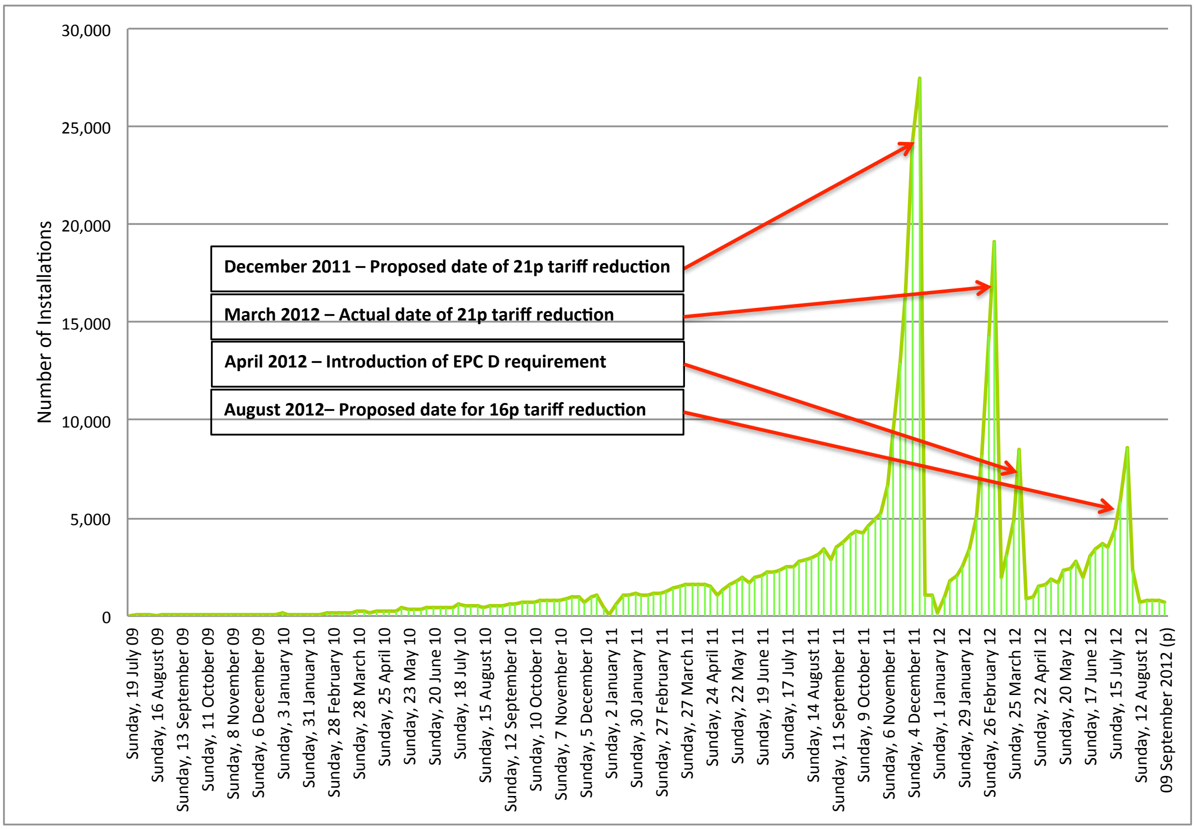
[33] A geared investment is one in which debt finance is introduced to lower the equity returns that must be honoured. Debt finance is effectively cheaper than equity because it is available at a pre-determined fixed rate independent of the profitability of an investment. So the higher the ratio of debt to equity, the higher the returns that an investor will receive.

FIGURE 6.4 NUMBER OF DOMESTIC SOLAR PV INSTALLATIONS PER WEEK, TARIFF BAND 0 -4 KW



Adapted from DECC (2012f)

This pattern of peaking installation rates has been challenging for the solar PV sector to respond to and many companies have gone out of business since the changes began. However, the tariff changes have also been used by solar installers as a marketing tool to encourage uptake before a deadline (Interview 1). But with the contingent regression model introduced on 1 November 2012 (see Chapter 5 Section 5.8.5), and the 3-monthly tariff reductions, these peaks are likely to be less pronounced going forwards because the cuts will be more frequent and less dramatic.

SECTION 6.3.1.6 DISTRIBUTIONAL IMPACTS OF SOLAR PV DEPLOYMENT UNDER THE FIT

The distributional trends of solar PV deployment indicate that installations are typically located in more affluent, higher energy-consuming households (DECC, 2012L). The upfront capital required for a PV installation remains as a barrier to many low-income potential generators (CSE and ACE, 2010). However, the FIT is funded by a levy on electricity bills and consequently all electricity consumers are contributing to the costs of the scheme. Therefore an increase in FIT deployment has an impact on all consumer bills which has been a controversial element of the scheme (CSE and ACE, 2010). This is discussed further in Chapter 8 Section 8.3.3.

SECTION 6.3.2 HYDRO SUMMARY

SECTION 6.3.2.1 HYDRO FIGURES

The number of hydro installations supported under the FIT is 324. 122 migrated from the RO so there are 202 additional schemes. The initial DECC modelling predicted that 216 additional schemes would be installed by the end of 2012 so deployment has been as expected[34]. The lead-time for a typical hydro scheme is 1 – 3 years and so there may be a lag in the figures and more schemes might be in the pipeline. One more figure of note is the increase in the average size of a hydro scheme under 5MW since the FIT was introduced. Using DECC's figures, the pre-FIT average capacity was 13.9kW (1700kW/122 installations). The average capacity as of 31 August 2012 was 88kW (28500kW/324 installations). This suggests an increase in commercial development of hydro as opposed to "hobby engineers" developing historic or bespoke schemes out of interest for the technology (e.g. old mill wheels). Mobilising the commercial sector is a significant development as they are able to complete schemes of a larger capacity and cost (Interview 36).

SECTION 6.3.2.2 HYDRO POTENTIAL

By DECC's own figures and aspirations the FIT has been a success for hydro. However the installation rate is modest despite a significant resource. The Environment Agency have identified over 25,000 sites suitable for small-scale, low-head hydro installations in England and Wales, 4190 of which are seen as "win-win" sites which '*are schemes that provide both a good hydropower opportunity, and could, through incorporation of a fish pass, improve the ecological status of the associated fish population*' (Environment Agency, 2010, p.1). In other words, there are 4190 profitable sites that the Environment Agency would grant the

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[34] This figure was shown to the author during an interview with an official at DECC.

necessary permissions to if they were sensitively developed. This resource is equivalent to approximately 1200MW of installed capacity (Environment Agency, 2010). But in the Impact Assessment accompanying the Governments response to the Comprehensive Review Phase 2B, DECC estimate that by 2020/2021 just 610 hydro installations representing 160MW will have been introduced since the introduction of the FIT (DECC, 2012c).

Government targets for the deployment of hydro schemes are low despite the potential resource identified by the Environment Agency. The tariffs set by DECC reflect this aspiration which effectively limits the potential for the hydro sector to develop the available resource. The 1200MW of potential capacity represents approximately 1% of UK generation capacity which understandably curbs the political enthusiasm and support for the hydro sector. But as the Environment Agency argue, hydropower is a reliable and proven technology that is ideal for community-scale development and is therefore worth pursuing. They also point out that to meet the challenging 2020 renewables target the UK '*will need to exploit all available renewable energy sources to their sustainable maximum*' (Environment Agency, 2012, p. 19) and 1200MW of reliable, predictable renewable generation is significant.

SECTION 6.3.2.3 BARRIERS TO HYDRO DEVELOPMENT

Unlike solar PV, hydro schemes have a natural brake on their development due to the project delivery characteristics. Each hydro scheme is effectively custom-built for the specific impoundment into which it is installed. Although the turbines and other components may be standardised their installation will be unique in each project. This requires design work for hydro developers which adds to the lead-time for an installation. Also, due to the sensitivity of the rivers into which schemes are placed, the Environment Agency have strict conditions of development (Environment Agency, 2009). The necessary permissions can include some or all of the following – an abstraction licence, an impoundment licence, discharge consent, flood defence consent, planning permission, a flood risk assessment and conservation approval from relevant organisations. In addition, detailed design drawings must be submitted for these permissions to be considered. Although this process is necessary, it can be burdensome for developers and it can take up to three years to complete. Navigating this period and complexity is a significant barrier for the development of hydropower and it largely explains the slow deployment rate expected and delivered under the FIT so far.

Phase 2B of the Comprehensive Review of the FIT introduced a number of changes affecting hydro schemes. A new intermediate hydro band was introduced in the range of 100–500kW, with a generation tariff of 15.5p/kWh. This was created to address a concern that the previous band of 100kW – 2MW was too broad which meant the support for a scheme at the lower end of the band was not sufficient. This resulted in developers under-sizing projects to receive the 15-100kW tariff. The new band should result in an increase in development of projects in the 100-200kW range, of which there are many potential opportunities in England and Wales (Interview 5).

As indicated in Chapter 5 Section 5.8.2, the introduction of Preliminary Accreditation is not likely to provide a significant advantage for the development of hydro projects. A developer must have already acquired planning approval, have evidence of a firm grid connection offer and have obtained any necessary environmental permissions in order to receive Preliminary Accreditation. These three stages are the biggest barriers to hydro development, requiring detailed and lengthy design work and a period of waiting and negotiation with the various different actors (e.g. Environment Agency, planners, conservation organisations). The actual construction and commissioning stage of a development will typically last only a small number of months. This change to the FIT is therefore unlikely to result in a significantly increased rate of development of hydropower schemes.

SECTION 6.3.3 WIND SUMMARY

SECTION 6.3.3.1 WIND FIGURES

The number of sub 5MW wind installations supported under the FIT was 3224 as of 31 August 2012, representing 79.97 MW. It is the second largest technology supported under the FIT with 1% of installations and 5.7% of capacity (DECC, 2012e and DECC, 2012g). The UK small and medium scale wind market up to 500kW is forecast to grow by 176% in 2012 and in general the sub 5MW wind sector is on an upward trajectory (RenewableUK, 2012). Prior to the announcement of the FITs the predominant installation size was sub 1.5kW, mostly off-grid (Element Energy, 2012). But numbers in this band are now in decline and as Table

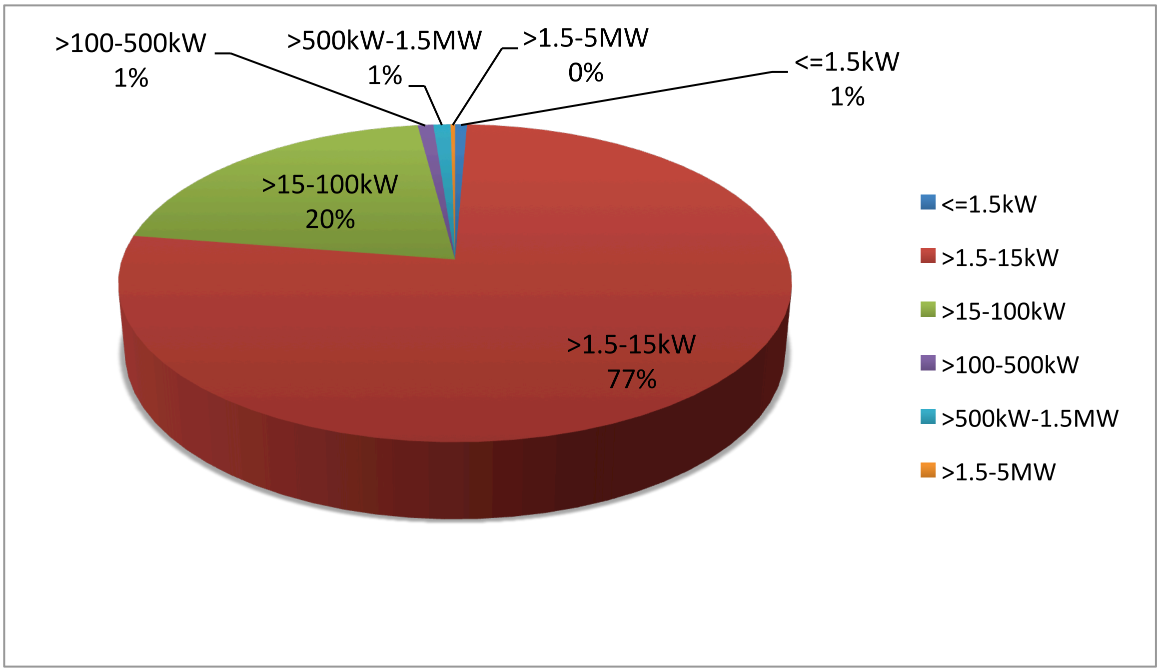
6.2 and Figure 6.4 show, the majority of FIT-supported wind is within the 1.5 – 15kW band. The FIT has thus significantly influenced the scales that are being deployed.

TABLE 6.2 WIND INSTALLATIONS AND CAPACITY AS OF 31 AUGUST 2012

Band	Number of installations	Total Capacity (kW)
<=1.5kW	16	21
>1.5-15kW	1,864	15085
>15-100kW	496	15471
>100-500kW	21	6880
>500kW-1.5MW	23	20120
>1.5-5MW	6	17300

Source: DECC (2012g)

FIGURE 6.4 PERCENTAGE SHARE OF WIND INSTALLATIONS UNDER THE FIT BY TARIFF BAND (%)



Figures sourced from DECC (2012g)

The reason for a surge in installations in the 1.5 – 15kW and 15 – 100kW bands is that this scale is ideally suited to off-grid sites, farms or community projects. The capex is relatively low, the development is reasonably simple, planning permission is easier to obtain than for larger turbines with a greater hub height, and the tariff is generous, providing a return on investment between three and eight years (RenewableUK, 2012).

But the larger bands have encouraged far less activity with just 6 installations in the 1.5 – 5MW band. A developer working with an established large-scale wind development company suggested that there were opportunities at this scale and the FIT had partially opened up the possibility of developing them. Her role had specifically been created to focus on these sites but she stated that they were not the priority of her company due to the fixed costs involved in installing large turbines (Interview 29). These fixed costs make larger sites, with more turbines and higher returns, more attractive to develop. The returns available from the FIT at this scale were generally not sufficient to compensate for the fixed costs of installation, which explains why the FIT has not mobilised wind development at this scale. However, there are some sites that are viable at this level but due to the longer lead times of larger projects there may be a lag in the FIT figures. The next 2 – 3 years will prove how successful the FIT has been at stimulating development over 100kW.

SECTION 6.3.3.2 BARRIERS TO WIND DEVELOPMENT

The initial modelling undertaken for DECC predicted that 7542 wind installations across all tariff bands would be supported under the FIT by the end of 2012 and the scheme has therefore fallen considerably short of its target[35]. The main reason for the shortfall in wind projects is the portfolio risk faced by wind developers (PB, 2012b). This includes technical risk and construction risk but the principal issue is planning. Planning delays and inconsistencies in the way planning applications are treated within local planning authorities remain the two biggest barriers to onshore wind developments at all scales. The rejection rate for applications up to 500kW is 11% according to an Element Energy survey of Local Authorities, and 10% of applications are withdrawn due largely to the stipulations made by planning authorities and committees (Element Energy, 2012). Just 40% of applications in the

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[35] These figures were shown to the author in an interview with an official from DECC.

100 – 500kW band are approved which can make wind development very expensive due to the perceived risk of rejection. But the time it takes to receive permissions also adds cost to a development with an average wait of 4 – 12 months, and occasionally far longer (RenewableUK, 2012).

The FIT does not help with the planning issue and despite the generous returns available under the scheme it will not achieve its potential as long as planning remains slow and inconsistent.

SECTION 6.3.4 ANAEROBIC DIGESTION SUMMARY

SECTION 6.3.4.1 ANAEROBIC DIGESTION FIGURES

AD has delivered the lowest deployment rates of the four renewable technologies supported under the FIT. Just 23 installations were receiving support as of 31 August 2012, representing 20.3MW (DECC, 2012g). The initial DECC modelling predicted 37 installations would be supported by the end of 2012 so the scheme is underperforming even by this modest target. The tariff for AD under 500kW was increased as part of the Fast-track review with a new band introduced which split into 13.6p/kWh for 250kW – 500kW and to 14.7p/kWh for <250kW. The tariff above 500kW was left at 9.9p/kWh (DECC, 2012c). The tariff was increased because just two schemes had been developed at the time of the consultation in March 2011. Although the installation numbers are now higher, 19 of the 23 schemes that exist are in the 500 - 5000kW band which has always had the same tariff. It seems as if there is still an issue with developing “farm-scale” sub 500kW AD plants which is the scale that DECC state is their priority (DECC, 2012e).

SECTION 6.3.4.2 BARRIERS TO ANAEROBIC DIGESTION DEVELOPMENT

AD development is a complicated and relatively new process in the UK in which there are a number of project risks that can become barriers to raising finance or developing a project. Glendale Power (2009) have outlined some of these risks –

1. Long-term contracts for feedstock – An AD plant requires secure access to feedstock for the life of the plant, or at least the length of the loan/payback period. Feedstock can include any biodegradable plant or animal matter but common examples are

slurry, manure, domestic and commercial waste, industrial food-processing waste, and silage (NNFCC, 2012). The AD project relies on the creditworthiness of the feedstock supplier because if they are unable to supply for any reason then the AD plant stops generating a return. Thus securing a contract with a reliable supplier is a critical stage but it can be a complex negotiation between several parties. As such it is perceived as a risk to a project.

2. Land title – Secure tenure needs to be guaranteed for the land on which the plant is sited. An AD plant situated on leased land introduces an additional third party risk to investment.
3. Waste-disposal - AD plants generate waste in the form of digestate. In some cases this can be used as a fertiliser but plant owners are unlikely to be paid for it and therefore need to demonstrate a contracted outlet to guarantee disposal. Finding a suitable outlet and negotiating a contract can hold up a development.
4. Grid connection – A lender (debt) would need to see a firm grid connection offer from a DNO before financing an AD project. An investor (equity) may be more willing to provide finance before a grid connection is guaranteed but the danger that connection is refused, comes with conditions, or is delayed adds risk to the project and therefore the investor would require a higher return.
5. Planning – as with wind development, planning is the most significant risk to an AD developer. Any delay in receiving permission can increase the costs of a scheme and a refusal can strand the early investment made in seeking permissions (Glendale Power, 2009).

These risks must be overcome before an AD scheme can be developed. Each risk can be complex and time-consuming and they can therefore add significantly to the lead-time and costs of a development and they explain why AD deployment has been modest under the FIT. Although the FIT tariffs provide a stable return, there are many issues that must be addressed before a project gets to that stage. Understanding and addressing these risks is critical if AD, and wind and hydro, projects are going to become a more significant part of the FIT scheme. This issue is picked up in Chapter 9.

SECTION 6.4 CHAPTER SUMMARY

This chapter has introduced the installation numbers and trends of the FIT scheme up to 31 August 2012. This showed that the FIT has delivered a large number of installations since it's introduction. The rate of deployment under the scheme is unprecedented in the UK with neither the NFFO, RO nor the various microgeneration grant schemes driving installation rates that are close to that driven by the FIT.

The chapter explained that solar PV has been the dominant technology and the vast majority of installations are sub 4kW domestic arrays. The high rate of solar PV deployment has been driven by a number of factors including the introduction of aggregated solar schemes, a higher than expected amount of commercial PV capacity, an underestimation of domestic hurdle rates in the initial modelling done for the FIT, and low interest rates elsewhere in the economy. But the principal factor is the 49-66% reduction in capex for a PV installation since the FIT was introduced. It has been difficult for DECC to respond to this unexpected level of capex reduction, and deployment has consequently been very high (DECC, 2011g).

The technology-by-technology summaries explained why hydro, wind and AD deployment has been so low in comparison to solar PV. This thesis argues that these technologies have a number of additional barriers to development that PV does not have, such as planning and licensing consents. It suggests that these need to be addressed directly if the non-PV technologies are going to be more widely deployed. It also argues that the example of solar PV shows that small-scale RE capacity can be delivered quickly if given the right support; this chapter has provided the background that will inform this argument in Chapter 9.

The next chapter provides a detailed analysis of the processes occurring at the niche level related to the FIT in order to evaluate the degree to which the FIT has built up momentum. It does this by applying the analytical framework adapted from Kern (2012).

CHAPTER 7 ANALYSIS OF THE GB FEED-IN TARIFF TECHNOLOGY-NICHES

SECTION 7.1 CHAPTER INTRODUCTION

This chapter analyses the impacts of the small-scale feed-in tariff at the niche level using the analytical framework adapted from Kern (2012). It directly answers Secondary Research Question 2 –

- Is the FIT driving a build-up of momentum in the FIT-technology sectors?

The analysis here, and in the next chapter, includes much of the information gained from the set of interviews that constitute the empirical core of this thesis. In addition, information acquired during the fieldwork and desk analysis is built in to the discussion. The niche indicators within the analytical framework provide the structure for the analysis below. The regime and landscape processes driven by, and related to, the FIT are explored in the next chapter.

Firstly it is important to recognise in the analysis that the FIT is only one policy mechanism within many. The development of small-scale RE is influenced by many factors and it is not always possible to isolate what is an impact of the FIT and what is driven by other developments. But every effort has been made in the analysis within the next two chapters to be clear about what distinctions have been made.

Although the FIT is only one of a suite of electricity policies, this thesis argues that in supporting some small-scale RE technologies under 5MW, it is stimulating growth in technologies that differ from the dominant characteristics, structure, and interests of the incumbent system. The diversity of ownership, technological characteristics and locations of the FIT technologies are a significant remove from the large-scale, centralised generation assets owned by the Big 6 energy utilities that dominate the prevailing electricity regime. Although the Big 6 own some FIT-supported technologies the number of generators recorded on the Central FIT Register was 216, 021 as of 31 August 2012 and the scheme has therefore introduced many new entrant generators (Ofgem, 2012b).

If the FIT were to be very successful and a high penetration of small-scale RE was achieved, the electricity system would be considerably different and a high degree of disruption to the status quo would occur. In this way the FIT has the *potential* to be a significant driver of transition in the UK electricity system and it is for this reason that the mechanism is the focus of this research. However, the potential of the FIT to deliver a radical change in the system is influenced by many factors, some supporting and some constraining, and this analysis seeks to bring these to light.

SECTION 7.2 NICHE DEVELOPMENTS UNDER THE FIT

As illustrated in Chapter 4, the analysis here splits each renewable FIT technology into its own niche. Each niche has characteristics that are unique to that one technology but also aspects that are interrelated with the other technologies in the scheme. Due to the dominance of solar PV under the FIT the majority of the findings from the fieldwork are specific to that niche and this is reflected in the analysis below. The analysis explores the niche processes, identified in the analytical framework (see Figure 7.1 below), in turn and discusses the degree to which they have been driven by the FIT mechanism.

FIGURE 7.1 NICHE PROCESSES

SECTION 7.3 LEARNING PROCESSES

Learning *effects* are the development of specialised skills and knowledge that accumulate through experience and increased production of a particular technology (see Chapter 3 Section 3.5). Arthur (1984) explained that these effects create increasing returns to cumulative adoption of a technology because the learning that occurs ultimately improves the productivity or performance of a technology. He argued that learning effects are a critical element in the selection of one means of production over another. Scholars of transition and MLP research suggest that learning *processes* are a necessary requirement for building niche momentum, indicating that learning must stabilise around one dominant, standardised design if development is to be focused (Geels and Schot, 2007; Verbong and Geels, 2007; Kern, 2012). Learning processes are here understood to be the means by which learning effects are realised and they are seen to include not just technical development and knowledge, but also the supporting practice development that can occur with cumulative production and use of a technology.

> *'(The FIT) is intended primarily to support the widespread deployment of proven technologies now and up to 2020, rather than to support development of unproven technologies....Taking that into account, on the launch of FITs in April 2010, we will only be offering tariffs to those technologies which we consider can realistically and effectively be deployed in the short term'* (DECC, 2010a).

As this quote from the Government Response to the initial FIT Consultation shows, the FIT is explicitly designed to scale-up deployment of market-ready technologies and so there will be some crossover between niches that are at similar levels of commercialisation. However, solar PV development has far outpaced the other technologies since the FIT was introduced and many of the learning processes discussed below relate to that niche alone.

The sections below explore those processes breaking them down into technological, commercial and organisational, and financial innovation and learning. As explained in Chapter 1, innovation is defined in this thesis in a broad sense as 'the production, diffusion and use of new, and economically useful, knowledge' (Lundvall, 1992, p.17).

SECTION 7.3.1 TECHNOLOGICAL INNOVATION AND LEARNING

Solar PV, wind, hydro and AD technologies are all operating in a global market and are influenced by developments beyond the UK and the support of the FIT. This is particularly true of solar PV technologies[36] which are developing rapidly in response to increasing global demand. By the end of 2012, it is projected that just 1.5 percent of cumulative global solar PV will be installed in the UK and the GB FIT is therefore a minor factor in the technological development that is occurring globally (CEPA and PB, 2011). However, it was evident from

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[36] 'Solar PV technologies' includes the module and an inverter

the fieldwork that a degree of technological learning was occurring in the UK as developers and installers gained experience of installation. This is most pronounced in the solar PV niche but there are also examples from wind and hydro developers that illustrate the benefits of a supportive policy.

An example of technological learning and innovation within the solar PV niche is a project run by Western Power Distribution (WPD) and Bristol City Council called So La BRISTOL. It is a project funded under the Low Carbon Network Fund which aims to trial solar PV systems connected into a battery store and a direct current (DC) network to be installed into participant's homes (Western Power Distribution, 2012). The aim of the project is to learn how to optimise the generation profile of solar PV in order to minimise peak demand on the distribution network. The project is one of many being supported under the Low Carbon Network Fund which allows up to £500 million of support to projects sponsored by the DNO's to experiment with advanced technologies and commercial arrangements that are expected to be a part of the low carbon networks of the future (Ofgem, 2011b). An interviewee, who is an Innovation Manager at a DNO, indicated very clearly that the high level of solar PV penetration that the FIT has driven has moved the challenge of integrating small-scale RE far higher up the innovation agenda for grid companies (Interview 31). The increased pace of solar PV deployment has therefore stimulated additional research such as the So La BRISTOL project and significant learning processes are in progress.

Cases such as the So La BRISTOL project are not directly linked to the FIT scheme but the level of pre-FIT solar PV deployment had not unlocked this sort of technological innovation and learning. Until a reasonable penetration of small-scale RE technologies is achieved it is very difficult to experiment with different ways of managing and optimising their performance. Another example that illustrates this was discussed in an interview with a solar installer who stated that the range of roof mounting systems for PV modules on the market has increased greatly since the FIT was introduced. Mounting systems for different roof types and for different weather conditions have been brought into the UK market in response to the increased demand (Interview 35). These products were developed and manufactured outside the UK and they would exist without the UK solar PV market but the FIT has driven a level of deployment, and crucially competition, that has encouraged developers in the UK to innovate and to experiment with enhanced installations.

This last point is an important factor in driving learning processes within a niche such as solar PV. The increased demand for installations that has been stimulated by the FIT has resulted in many new-entrant installers coming into the sector. This has increased the competition between companies who must seek ways to differentiate themselves. One outcome of this has been the introduction of innovative technical solutions to problems, such as alternative roof mountings. This technological learning is difficult to value but it is a significant factor to consider in evaluating the wider impacts of the FIT.

A further example of this form of technological learning was illustrated by a small-scale (~10kW) wind developer who discussed the improvements his company had made in laying foundations for ground-mounted wind turbines. Each turbine is installed under unique conditions and into varying landforms and he argued that the increased demand for small wind under the FIT had allowed them to experiment and to test different options.

'*One has to prove a technology in terms of technical reliability. You have to know that they're going to perform in all sorts of conditions and you can't do that with one or two machines, you've got to have a lot of them out there. You've got to get over the teething problems, it's a learning curve and the whole industry has had to get itself geared up. That underpinning is very important*' (Interview 15).

As the quote above argues, a reasonable level of deployment is required in order for developers to innovate through experience. The wind banding that has seen the most growth under the FIT is the 1.5 – 15kW band which represents 77% of all installations. A RenewableUK report on the Small and Medium Wind market states that the FIT has effectively created this sector in the UK because before the scheme was introduced this scale was not economically viable for on-grid sites (RenewableUK, 2012). Therefore in this example, the FIT has driven a level of deployment that has fostered the development of the learning processes required for the development of niche momentum.

Another development outside of solar PV that highlights the learning processes stemming from increased deployment has been the improvement of fish passes for micro-hydro installations. Virtually all low-head run-of-river installations are on sites where impoundments already exist and infrastructure is present in the river. A typical Environment Agency (EA) stipulation, in exchange for licensing, is that the fish passes are improved and the agency is able to request specific designs and criteria. This has driven the development of fish passes that meet the increasingly stringent EA stipulations, which is a response to the higher number of licensing requests that they are receiving (Environment Agency, 2009). There is a perception from hydro developers that the EA are aware of the increased revenue being received by generators under the FIT, and they are responding with higher demands for licensing (Interview 5 & 36). This same trend is also driving the development of more advanced flow-regime control systems as the EA seeks to improve the ecological conditions of rivers. The 4190 'win-win' sites identified by the EA (see Chapter 6 Section 6.3.2.2) are viewed to be good opportunities because they provide good hydropower potential but could also improve the ecological status of the river if sensitively developed (Environment Agency, 2010). The stipulations made by the EA to ensure that the ecological conditions are improved can create tension between planners, developers and the EA, which slows the rate of development but it can also be creative in driving the sort of innovation outlined above.

These developments have come either as a result of the increased scale of installations, and therefore experience, or as a result of the higher revenue received under the FIT affording more opportunity for experimentation. Developers of all four FIT technologies indicated that either DNO's, licensing authorities or planning committees were more stringent in their application consideration since the introduction of the FIT. They are demanding more from developers before permissions are granted or a grid connection offer is made. This is driving learning processes within the four renewable FIT niches, particularly in the solar PV niche where cumulative installations have been so much higher.

As this section has shown, the FIT has had a number of positive technological spill-over effects which constitute the learning effects discussed by Arthur (1984). However, it is hard to quantify the impact of these effects; innovation is a non-linear process that is difficult to singularly analyse (Smith et al. 2010). This has been a problem for the FIT as it has come under closer scrutiny due to the introduction of a spending cap and because of the high solar PV installation rates. The spill-over effects are not transparent or accountable and are therefore viewed by Government as externalities to the main objectives of the policy (Interview 16). But the contribution of this thesis is to consider those externalities for their role in a wider process of electricity system transition in the UK. The examples outlined in this section are illustrative cases of the breadth of influence a support mechanism can have. Technological learning and innovation is occurring as a result of the installation increase, and higher revenues, stemming from the FIT. It is important to consider these impacts when evaluating the impacts of the scheme; something that is missed by conventional policy analyses.

SECTION 7.3.2 COMMERCIAL AND ORGANISATIONAL INNOVATION AND LEARNING

The rate of uptake under any support mechanism would be expected to increase as an industry responds to the opportunity and builds capacity. It takes time for the commercial actors to “productise” a policy such that the support available can be sold as a marketable package (Interview 16). The sub 5MW solar, wind, hydro and AD sectors in the UK were small and relatively undeveloped before the FIT was introduced and a degree of commercial development has had to occur in order to create and respond to the increased demand for installations. This section explains two key developments relating to the commercial aspects of solar PV – aggregated schemes and stand-alone solar. These examples demonstrate the way in which commercial learning processes have been driven by the FIT.

SECTION 7.3.2.1 AGGREGATED SOLAR PV SCHEMES

One of the more innovative models of solar PV installation that has developed out of the FIT is the aggregation of multiple schemes financed by one central organisation that claims the FIT payments, but allows the roof owner to use the electricity. These are commonly termed “rent-a-roof”, “funded solar” or “aggregated” schemes. These schemes represent around 20% of the installations currently registered for FITs (DECC, 2012a). A Shade Greener pioneered this approach by offering free solar PV installations to south facing roofs large enough to accommodate a 3.3kW array that were within a one hour drive of the company’s warehouse in Rotherham. This combination of factors allowed the company to achieve economies of scale which made the potential return on investment high enough to raise finance for an initial 6000 installs (Interview 4). They have now completed more than 13,500 installations (A Shade Greener, 2012) which has encouraged other businesses such as HomeSun and British Gas to follow similar models.

This is an example of the learning processes included within the analytical framework because it is an innovation that has developed out of increased sector experience. This commercial innovation allows aggregators to achieve scale within the fragmented PV market and to attract finance for a scheme with stable returns (see Section 7.3.3).

But this innovation is also significant because other companies and organisations have followed this model and attempted to introduce similar schemes. An interviewee who is Head of Policy at one of the Big 6 electricity suppliers discussed how innovative actors such as A Shade Greener did the hard work by forging a new direction and making it successful. Players such as the Big 6 then respond to this and follow a similar business model, as the quote below illustrates.

'Originally, when we first started our (solar PV) business it was looking at straight sells to households in the summer of last year (2010). There were quite a few new free solar schemes out there so we had to look at how that would work, which was change 1. Change 2 was around the end of last year, there were a lot of the large scale solar projects so we were looking closely at what others were doing and talking to a lot of people about those and how we could make those work. We've found the domestic market is just so fragmented and the only way that a large company can differentiate itself and get real volume is what we saw happening in free solar' (Interview 4).

Hockerts and Wustenhagen (2010) discuss the impacts of new entrants such as this, suggesting that as transitions to sustainable systems progress there is an on-going interaction between innovative entrants (who they term emerging David's) and incumbents (who they term greening Goliaths). Incumbents react to the innovation of new market actors (and the potential competitive threat that they pose) by building sustainable practices into their own activities. Although this may be in a diluted form, the impacts have a broader reach due to the larger market presence of incumbents. Hockerts and Wustenhagen suggest that this relationship continues in a co-evolutionary manner that results in the sustainable transformation of industry (2010). It is too early to tell the degree to which the larger incumbent firms in the electricity sector are responding to the commercial practices of new entrants supported under the FIT but the quote above suggests that learning processes are occurring in the sector, different companies are responding to the success of their competitors and commercial innovation is spreading.

In addition to new commercial entrants, some Local Authorities (e.g. Birmingham City Council), Housing Associations (e.g. Hafod Housing Association) and community groups (e.g. Wadebridge Renewable Energy Network) have also financed multiple installations on houses, schools and public buildings. These groups often have lower hurdle rates than commercial businesses and are therefore able to install in sub-optimal locations where other motivations predominate such as addressing fuel poverty and carbon reduction (Interview 24 & 27). The revenue available from the FIT, particularly for solar PV before the tariffs were reduced, has opened up the opportunity for these groups to explore options for developing RE. Aggregated schemes offer the opportunity for collective purchase at reduced costs, but they also present a more attractive model for third party investment. This is discussed in Section 7.3.3.

Aggregated schemes have been a controversial development, due largely to some aggressive marketing techniques from companies seeking to ensure multiple sales within a specific area (Interview 32). But they have also been welcomed because they overcome the barrier of upfront capital required for PV installations. This has provided access to small-scale RE for lower-income homeowners and tenants that are unable to raise the required investment. This commercial innovation has therefore had a significant impact within the solar PV sector in introducing a unique business model that potentially has a very broad application. The following section outlines another commercial innovation that has developed in order to achieve scale in solar PV installation.

SECTION 7.3.2.2 GROUND-MOUNTED SOLAR PV

Another unanticipated outcome from the introduction of the FIT was the development of ground-mounted solar PV “farms”. As stated above, DECC did not foresee any large solar PV installations until at least 2013 and they were therefore surprised by the activity at this scale. As of 31 August 2012 there were 713 stand-alone[37] installations representing 117.7MW, or 9.3% of total solar PV capacity. The existence of ground-mounted solar is itself an innovation for the UK where no large site had been developed before the FIT (DECC, 2011e).

The assumption that there would be no ground-mounted projects was based on an estimated hurdle rate for commercial investors and the tariff was set at a level that would not deliver these rates until 2014. However, the potential return from a solar array will be heavily influenced by the solar irradiation at the individual site. The tariffs do not account for location and so a site in Cornwall with irradiation levels of 1050 – 1100 kWh/m2 will have a higher load factor[38] than a site in Nottingham with irradiation at 900 – 950 kWh/m2. The original tariffs were set using the Governments 2009 Standard Assessment Procedure figures which were based on a location in Birmingham. Consequently anywhere south of that location will achieve higher returns than predicted in the modelling, making the south of England, and Cornwall and Devon in particular, very attractive for investment. In addition, large ground-mounted sites typically export 100% of their generation but the DECC modelling assumed 50% of electricity generated would be consumed on-site for all solar PV installations. The initial stand-alone tariff did not make exception for this and the rate was the same as the 100kW – 5MW on-site tariff. This further increased the potential returns available for the larger export-oriented projects (CEPA and PB, 2011).

Stand-alone PV systems up to 5MW located in the south of England offered an attractive investment opportunity under the original tariff levels with guaranteed returns up to 13%, and a relatively straightforward installation (Interview 3). Consequently there was a great deal of interest in this area, and Cornwall Council in particular received a large number of planning applications towards the end of 2010 and the first half of 2011 (Interview 2). They had granted permission to 23 sites totalling 105MW before DECC announced the fast-track review (see Chapter 5 Section 5.8.2) of the scheme but the interest shown in the sector from domestic and international investors and developers was enough for DECC to drop the

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[37] A stand-alone system is one that is ‘not attached to a building and not wired to provide electricity to an occupied building’ (DECC, 2010a, p.47). There may be a very few examples of ground-mounted PV schemes which are not stand-alone, and these would not be captured in these figures.

[38] A load factor is the ratio of actual output of a power plant to its potential maximum output

tariff for stand-alone systems from 29.3p/kWh to 9p/kWh. However, in the short period open for development at the larger scale, the industry responded quickly. The opportunity to install under the FIT drove innovation by commercial developers and associated organisations in a design of installation not previously undertaken in the UK. There were a number of learning processes discussed by interviewees working in this area, discussed below.

Due to the unexpected nature of the interest in ground-mounted solar PV installations there was a lack of planning guidance for affected councils and planning committees to work with. Cornwall Council developed the first planning guidance document which has been used as a basis for all UK councils looking at solar PV applications over 50kW (Cornwall Council, 2012). Although this constitutes statutory work for planning departments, the lack of guidance before Cornwall Council developed this document could be seen as a barrier to effective or appropriate development. Something has to stimulate activity in a new area before deployment can proceed and the FIT has been argued by many interviewees to be a good example of that “pump priming” of an industry (Interviews 16, 26 and 4). A bulkhead of activity is required before the details of small-scale RE development, such as planning guidance, can be dealt with. Although this may be an expensive stage, as it was for ground-mounted solar PV, it is necessary for progressive innovation, assuming that costs will later fall.

As Section 7.4 explains, costs of solar PV technologies have fallen dramatically in recent years. An argument made by an interviewee from DECC against high-cost support for stand-alone solar PV was that the UK was a “price-taker” within the global market and that it would be more cost-beneficial to wait until global prices reduce before the UK supports solar PV at this scale (Interview 19). But although the technology represents the principal element of the capex[39] of an installation, ranging from 35% - 55%, it is only one part of the costs (PB, 2012). There are other costs including additional components, construction, and fencing. These are dependant on a supply-chain that takes time to develop. A further example of the commercial and organisational innovation that occurred within the ground-

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[39] Capex of a PV installation includes PV module, inverter, other component costs and project costs (PB, 2012).

mounted solar space is related to supply-chain development, here illustrated by an interviewee from Cornwall Council –

‘(We) set up a database of companies that can help to develop and maintain solar farms in Cornwall. So if you are a plant hire company, or electrical engineers, fabricators, welders, earthworks, fitters, electricians, landscapers, fencers, security, we want you on that register for when these companies come forward and say we need this’ (Interview 2).

This co-ordinating work by Cornwall Council facilitates the development of solar in the county and reduces the project costs for developers who can gain quick access to local skills (Interview 1 & 3). It also develops the expertise of contractors in the area rather than developers hiring in experienced teams from countries with established ground-mounted industries (e.g. Germany, Spain). However, the ground-mounted tariff was the first to be cut under the FIT, as explained in Chapter 5 Section 5.8.2. The announcement of the tariff cut had a huge impact on the ground-mounted industry with projects either being rushed in order to make the cut-off date for the reduction, or projects being abandoned. Some developers sought to make use of a loophole in the FIT legislation that would allow them to extend existing sites and receive the original tariff but this loophole was later closed by DECC (DECC, 2011f).

The installation rate for ground-mounted solar dropped completely following the fast-track review but a number of interviewees argued that the lasting impact was to damage the solar industry’s confidence in DECC (Interview 22, 9, 25). The speed with which the tariff was reduced surprised many interviewees. The quotes below illustrate the anger expressed by many within the industry.

TABLE 7.1 INTERVIEWEE QUOTES RELATING TO THE FAST-TRACK REVIEW

Quote	**Stakeholder**
DECC has shown itself to be remarkably inept. Really surprisingly. How did it manage to screw up the FIT so very very very much? It has really damaged everyones confidence that they won't just change the rules whenever they want.	UK based solar developer and energy lawyer (Interview 25).
For the players involved in the FIT it has been a textbook example of policy risk and how not to do something.	Energy consultant (Interview 12).
So actually the worst case (FIT scheme), the number 1 worst case has been the UK.	Germany-based ground-mounted solar developer (Interview 11).

Policy risk and change will be explored in greater depth in Chapter 8 but of relevance here is the impact that policy change has had on commercial and organisational innovation. The FIT related small-scale RE sector is still a nascent industry, relative to the electricity regime, and the innovation that has occurred is still at an unstable stage. For learning processes to consolidate such that a niche technology may break through into the regime, a degree of protection is required. As Raven suggests, there are five main methods of creating protection for innovation processes – economic, institutional, socio-cognitive, political and geographical (see Table 3.1) (Raven, 2010).

The GB FIT provides economic protection through the tariffs received by generators, institutional protection by guaranteeing offtake and grid connection, and political protection through the implicit inclusion of small-scale RE within Government strategy. However, changing the policy, adjusting tariff levels, and creating uncertainty in the small-scale RE sector within one year of introducing the policy disturbs that protection at a vulnerable time. Learning effects occur over the long-term and require a consistent protective space to thrive (Raven, 2010). The advantage of the FIT design is that it provides the opportunity, through the degression of tariff levels, to withdraw protection incrementally. But DECC struggled to manage the scheme effectively in its first two years and support was not reduced along a transparent gradient. Rather, policy change has been reactionary, particularly for solar PV, which has created uncertainty for the sector and endangered the commercial learning processes that have occurred.

However, despite the difficulties that the FIT changes have created for ground-mounted solar, one interviewee has recently (mid-2012) applied for permission to develop a 25MW solar PV project in Cornwall which will be supported under the RO. Although at present there are no solar installations over 5MW in the UK a recent RO consultation indicated that approximately 120MW have already been consented (DECC, 2012h). These projects would receive the same support provided to offshore wind which is the marginal technology for large-scale renewable support from DECC. This means DECC will not significantly support technologies that cost more per MW than offshore wind but technologies under that level are eligible for support (DECC, 2011h). If ground-mounted solar is competitive with offshore wind in the UK then it is likely to have a future in the electricity system. There are other factors to consider such as whether solar is an appropriate use of agricultural land, and future planning concerns that may arise with cumulative development. But in terms of costs alone, ground-mounted solar PV is increasingly viable. The principal factor explaining this development is the global reduction in module costs but it is likely that the commercial innovation and learning that has occurred under the FIT has helped to develop ground-mounted solar as a feasible generation option.

SECTION 7.3.3 FINANCIAL INNOVATION AND LEARNING

One further indication of the learning processes being driven by the FIT is the degree of financial innovation and learning that has occurred in response to the returns available for solar PV. This was expressed by an interviewee from one of the Big 6 -

‘A lot of the innovation under the FIT has been financial innovation, that’s what’s been leading the charge. That was behind a lot of the large scale solar parks and free solar…That’s been one of the key reasons why FITs have been a far greater success than anyone imagined’ (Interview 4).

SECTION 7.3.3.1 PROJECT FINANCE AND SPECIAL PURPOSE VEHICLES

As discussed above, solar PV is a fragmented market and it is difficult for a company to scale-up its business because it has to deal with so many individuals in different locations who need to find the initial capital outlay. But larger scale solar installations and aggregated solar schemes were able to bypass this issue and investment models designed for this purpose have developed rapidly.

The aggregated solar model allows companies and organisations to target specific areas where they could achieve efficiencies in installation and at numbers that drove economies of scale. But also, by financing the scheme centrally, companies such as British Gas and some Housing Associations and Residential Social Landlords (RSLs) have been able to develop project finance models which are not possible for the fragmented domestic market (Interview 4, 16, 20). This usually involves the setting up of a stand-alone project company, or Special Purpose Vehicle (SPV), which holds the solar assets and acts as the contractor with third parties such as grid operators, suppliers, lenders, and investors (Goldman *et al.*, 2005, Interview 4). The repayments of any loan are determined by the cashflow of the SPV and the lenders only have recourse to the SPVs underlying assets – not the assets of the larger company or association. This is attractive for large companies with diverse portfolios because it insulates the rest of the business from the risks associated with the SPV and solar PV development, and it also provides a platform for attracting both debt and equity finance for companies struggling to leverage debt on the strength of their balance sheet assets (Interview 16). It is also very attractive for Local Authorities with budgetary constraints because the stand-alone status of the SPV moves the capital-intensive solar PV investment off the balance sheet of the central association.

Some of the larger-scale solar developers who were interviewed explained that the project finance model allowed a company, before the Comprehensive Review, to gear the investment within the SPV to increase the equity returns to 15 – 20%, and also to eventually sell the whole project company to a larger risk-averse investor such as a pension fund (Interview 3 and 4). Project finance is an increasingly standard means of financing renewable energy projects at the larger scale but it is a new development for solar PV that has been driven by the scale opportunities possible under the FIT. It is yet to be seen how aggregated solar developers, Local Authorities, Housing Associations, RSLs or community groups will respond to the new tariff levels and the reduced rate of 90% of tariffs available to individual installations, but this financial innovation has increased the investment potential of solar PV under this model.

SECTION 7.3.3.2 NEW MARKET ENTRY AND VENTURE CAPITAL TRUSTS

Accessing finance is one of the biggest barriers for FIT developers and it is particularly difficult for new market entrants as explained by a solar developer –

*'The FIT had been stopped in Italy and in Spain so all those funders and companies that had been built up in those particular countries came to England and because a lot of those companies had already delivered projects they'd already got the confidence from people putting money in. So when we came along and said we want to build a solar farm they said "no, no you can't do that. Get this Spanish company to do it, they've done it before." No-one wanted to give an English company the opportunity to do that. So off you went down to Benbole (*a solar farm*) when it was being built and nobody on site could speak English!'* (Interview 1).

The lack of experience, collateral, and credit rating that new entrants have raises their risk profile and consequently increases their costs of capital. A source of finance that is more accessible to start-up businesses is Venture Capital and a significant development for the commercial solar PV sector has been a growth in solar Venture Capital Trusts (VCTs). VCTs and are tax efficient private equity schemes that invest in a portfolio of high-risk projects and small companies. Before April 2012 (when they were investing in solar projects) they offered investors 30 per cent upfront tax relief on annual investments up to £200,000, which attracted much interest since they were introduced in 1995 (HMRC, 2012). VCTs such as Octopus, Beringea, and Foresight have chosen to invest in commercial solar PV because it qualified for VCT finance but offers a stable return once operational (Interview 26, Vincent/Financial Times, 2011). This opportunity was a key reason why so much interest was stimulated in ground-mounted PV during 2011, and consequently why DECC feared the potential pace of development that this would create. VCTs later centred on commercial rooftop installations (Interview 17) but as of April 2012 VCTs (and similar Enterprise Investment Schemes [EIS's]) were prohibited from investing in FIT-supported schemes. This was due to a perceived over-provision of support in the form of tax relief and the feed-in tariff subsidy (HMRC, 2011).

Solar VCTs, and EIS's, provided a vehicle for injecting large amounts of capital into the solar PV space and they represented some innovation in the financing of small-scale RE. In general, there is now a far better understanding amongst investors of solar PV as an asset class post FIT introduction, which is resulting in some innovative funding models coming forward, such as the SPV and solar VCTs described above. This innovation is positive in that large amounts of capital are required if the FIT technologies are to make a realistic challenge to the incumbent electricity regime but it has also been met with caution by some interviewees who are watchful of the implications of the solar PV niche moving into the mainstream.

The larger, more sophisticated investors that have begun to move into the PV space are primarily interested in allocating capital wherever they can in order to maximise their returns. This route moves away from the diversity that is typical of small-scale investment and it is perhaps further removed from the interests of the small-scale RE sector. As an equity investor explained -

Basically those big institutional investors, what they're interested in is getting the best returns for the risk and making sure they can pay their obligations to the pension companies or the insurance beneficiaries. You know, they're not there to do social investment to meet the Government's needs. That's how they view a lot of this stuff but they do bring a lot of capital (Interview 28).

Investment decisions at this level can seem fickle to those working within a sector such as small-scale RE because, fundamentally, they are made on the basis of profit and the capital is mobile. One reason solar PV has received such interest is its increased attractiveness following the financial crisis of 2008. As an investor explains -

'Q*uite a few companies were attracted into the space because of the fact that it was an index linked product so you've got an attractive yield that was index linked. That became super-attractive at a time post financial crisis when you can't get yield for anything. So* *everybody, all the pension funds, everybody is suddenly massively incentivised by yield…So a lot of financial players were just seeing it as a way of parking money* (Interview 16).

It was suggested that this is not financial innovation in the solar space, but rather a temporary opportunity that may as quickly disappear as it arrived (Interview 24). The impact of this investment was also questioned –

'*There has been some investment but how useful that investment has been in terms of driving innovation I would question*.' (Interview 12).

There are differing opinions on this between the interviewees in this study but all recognised that the increase in large-scale equity investment marked a significant development for the solar PV niche. It represents a learning process in the innovatory and novel approaches to financing a niche technology but is perhaps more significantly an attempt by regime actors (investors) to move into the sector and escalate the scale of deployment. This is discussed further in Section 7.5.

SECTION 7.3.4 LEARNING PROCESSES SUMMARY

This section on learning processes stemming from the FIT has shown that a number of technological learning effects are evident from interviews with those working in the various niches but that solar PV has seen by far the most activity and development. These developments have come either as a result of the increased scale of installations under the FIT mechanism, and therefore more experience, or as a result of the higher revenue received under the scheme affording more opportunity for experimentation. Many of these effects are spill-overs which would not be acknowledged in conventional policy analyses. They are however, a significant development in the FIT-related small-scale RE sector.

The solar sector has also responded to the opportunities of the FIT through commercial innovation. The challenges of building capacity, productising a policy and finding ways to scale up deployment have been afforded by the bulkhead of installations that the FIT has created. There is also a degree of learning between various actors in the sector, which shows signs of the co-evolutionary development discussed by Hockerts and Wustenhagen (2010). However, these developments have been threatened by the way in which the scheme has been managed and changed and it remains to be seen how the industry will continue under the newer FIT design.

There has also been some significant financial innovation related to solar PV as actors have sought novel ways to fund FIT schemes. More sophisticated investors have moved into the solar PV space which is viewed as progress by some stakeholders but insignificant by others. But certainly it marks the increasing presence of regime actors in the FIT niches, a process which transition scholars have highlighted as a crucial step in building niche momentum. The role of these learning processes in a wider process of system transition is picked up in Chapter 8 which discusses the broader implications of the analysis here.

The following section addresses another crucial process for building niche momentum, the improvement in price-performance of niche technologies.

SECTION 7.4 PRICE-PERFORMANCE IMPROVEMENTS

The most significant price-performance factor affecting the FIT scheme has been the sharp decline in solar PV module costs. Technologies in the other FIT niches have not experienced the scale effects which should drive these reductions, but the solar PV developments illustrate well the impact that cost reductions can have on deployment levels. This section begins with an overview of the price-performance figures for wind, hydro and AD. It then moves on to analyse in more detail the improvements within solar PV. The analysis focuses on price improvements because the reduction of costs has been the main focus of renewable technology manufacturers and developers (EPIA, 2012; PB, 2012b). Improvements in performance that are related to the FIT are discussed in Section 7.3.1.

SECTION 7.4.1 PRICE-PERFORMANCE OF HYDRO, WIND AND AD

The figures in this section are based on a report commissioned by DECC in 2009 on the 'Quantitative Issues of FIT Design' (Element Energy and Poyry Consulting, 2009) and a report from July 2012 providing an update on non-PV data for DECC (PB, 2012b). It should be noted that there is a high degree of uncertainty over the capex for all RE technologies because there are so many variables to consider. These include installation design, plant acquisition, delivery, installation, commissioning, wage rates, exchange rates and interest rates. These all vary across projects and over time and it is therefore difficult to isolate the main cost-reduction drivers.

The figures in the table below are estimations of the capex (£/kW) of wind and hydro at different scales based on consultation with the respective industries. The figures represent the total capex for the given technology including design, plant acquisition, delivery, installation, and commissioning. The costs do not include VAT.

TABLE 7.2 INSTALLATION COSTS OF WIND AND HYDRO IN £/KW

Wind	2009	2012	**Hydro**	2009	2012
<1.5kW	5500	No data	**1 – 10 kW**	12200	9500
1.5 – 15 kW	12000	5250	**10 – 50 kW**	13000	7000
15 – 50 kW	3000	4200	**50 – 100 kW**	3200	6650
50 – 250 kW	3000	3588[40]	**100 – 500 kW**	3000	4500
250 – 500 kW	2500	2750	**500 – 1000 kW**	2750	4500
500+ kW	1500	1930 - 2200	**1000+ kW**	2250	2700 - 3300

Source: Element Energy and Poyry Consulting, 2009 & PB 2012b

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[40] The actual FIT bandings differ from the bandings assumed in the Element Energy and Poyry (2009) report. The FIT figures from the 50 – 100kW band are used here in the 50 – 250kW band, and the 100 – 500kW figures are used here in the 250 – 500kW band.

The capex of wind has increased in all but one band which is 1.5 – 15kW. This increase has been driven in part by higher metal prices and also the removal of cheaper low performance turbines from the market (PB, 2012b). But interestingly, the one band that has reduced in capex is also the band with the highest installation rate with 1,864 schemes supported. As discussed in Chapter 6 Section 6.3.3, the FIT has created the opportunity for this band to develop and it appears that this has had a significant impact on costs. However, across the bands it is predicted that the capex of wind will flat-line until at least 2017. Although some of the costs of installation may fall as the sector becomes more experienced, this will be counterbalanced by increasing material prices (PB, 2012b).

The hydro sector is in a similar position with the majority of bands increasing in capex due to material prices. Developers are also suggesting that the more stringent licensing requirements are driving up the capex of installations and that the increase in deployment levels does not reduce costs because there is little opportunity for standardisation, and thus economies of scale, in hydro schemes because every impoundment has different requirements (Interview 36 and PB, 2012b). Also, hydro is a relatively mature technology and there is limited scope for further efficiencies to be found in installation. But also the lower cost, more accessible sites have already been developed and the remaining impoundments will become increasingly expensive to develop. It is predicted that hydro capex will also flat line over the next few years (PB, 2012b).

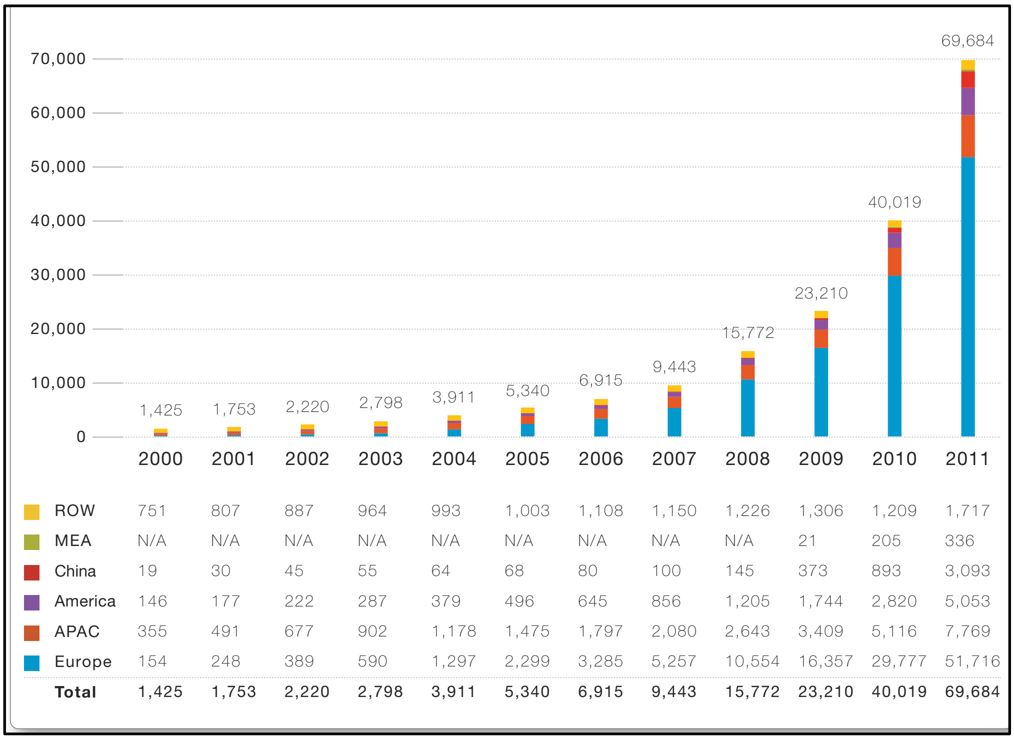
AD is still a nascent industry and there is very little comparable data. Capex now ranges from £4500 - £6000 per kW but there are not sufficient numbers of AD plants installed in the UK to predict with certainty whether costs will reduce. However, there is the potential for standardisation at the smaller bands which could drive economies of scale and one interviewee suggested that a British company is currently developing a low-cost small-scale AD facility that is designed specifically for the UK market under the smallest FIT banding (Interview 37). But AD technology is complex because it has to abide by UK waste regulation, and EU digestate standards. Many AD plant are manufactured in Germany and then have to be adapted for installation in the UK which increases their costs. It is difficult to predict accurately but broadly, AD capex is expected to remain flat over the coming years (PB, 2012b).

There is little sign of capex reduction in the wind, hydro and AD niches and there is no indication that this will change in the future under the predicted deployment levels. The price-performance improvements that are a requirement within the analytical framework are not occurring in these niches.

SECTION 7.4.2 PRICE-PERFORMANCE OF SOLAR PV

The reductions in the capex of solar PV have been driven principally by global trends beyond the scope of the GB FIT. Global PV capacity grew from 23GW in 2009 to more than 69GW in 2011 producing 85TWh of electricity per year (EPIA, 2012). This extreme growth is illustrated in Figure 7.2 below, showing installed capacity since 2000.

FIGURE 7.2 GLOBAL INSTALLED CUMULATIVE SOLAR PV CAPACITY 2000 - 2011



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
🟨 ROW	751	807	887	964	993	1,003	1,108	1,150	1,226	1,306	1,209	1,717
🟩 MEA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	21	205	336
🟥 China	19	30	45	55	64	68	80	100	145	373	893	3,093
🟪 America	146	177	222	287	379	496	645	856	1,205	1,744	2,820	5,053
🟧 APAC	355	491	677	902	1,178	1,475	1,797	2,080	2,643	3,409	5,116	7,769
🟦 Europe	154	248	389	590	1,297	2,299	3,285	5,257	10,554	16,357	29,777	51,716
Total	1,425	1,753	2,220	2,798	3,911	5,340	6,915	9,443	15,772	23,210	40,019	69,684

Source: EPIA (2012).

This global market growth has been driven by a number of factors including -

1. Countries such as Germany, Italy and Japan have increased their focus on solar PV, and renewable energy in general, in the wake of the Fukushima nuclear accident, with policies driving rapid expansion of the market;

2. In some countries, such as the UK, uncertainty over the future of support schemes has produced boom-and-bust cycles that have resulted in sharp peaks in deployment;

3. Solar PV modules have undergone significant price decreases, reducing the installation costs and thereby stimulating demand (EPIA, 2012).

This last point is explored further in the following section.

SECTION 7.4.2.1 SOLAR PV MODULE PRICE

A central factor driving the rapid uptake of solar PV since the introduction of the FIT has been a crash in the price of silicon in 2010, one of the principal materials in most PV modules (Element Energy, 2011). There has also been an oversupply of modules on the global market as manufacturers in China and the US have competed fiercely for dominance. Several Chinese manufacturers were found, by the US Department of Commerce, to be 'dumping'[41] subsidised modules in an attempt to drive out competing manufacturers (Department of Commerce, 2012). The consequence of this competition has been to drive down module costs. See Figure 7.3 below. As of April 2012, the factory-gate selling price of modules was approximately 53p/watt for Chinese multicrystalline silicon modules and 63p/watt for non-Chinese monocrystalline silicon modules, down from an average price of £1.87/watt in 2003 (BNEF, 2012).

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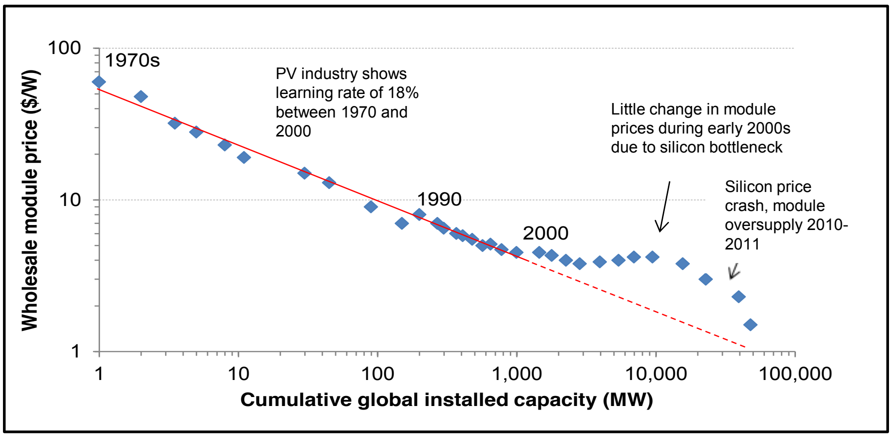
[41] Dumping is a predatory pricing policy whereby products are exported to another country, either at prices which undercut the home market or in such high volumes that the market price crashes. This policy is used to gain dominance in an emerging market (Department of Commerce, 2012).

FIGURE 7.3 HISTORICAL TRENDS IN GLOBAL PV MODULE PRICES



Source: Element Energy (2011)

SECTION 7.4.2.2 SOLAR PV INSTALLATION COSTS

As discussed above in Section 7.3.2 the physical modules represent the principal element of the capex of a solar PV installation in the UK, ranging from 35% - 55%, and they have been the primary cost reduction driver (PB, 2012). But there are additional costs such as inverters, fixings and other components, labour, scaffolding, transport, additional overheads, and profit margins that are also significant aspects of full capex. Globally, the balance-of-system[42] components have experienced a learning rate[43] of 19% to 22% (IPCC, 2012). The price of inverters has dropped from an average of 18p/W in 2007 to under 12p/W in some cases in Q1 2012 (IPCC, 2012; Baziliana et al. 2012).

The non-module elements of PV capex have become an increasing proportion of the total costs as module prices have reduced. Figure 7.4 below shows an estimate of the weighting of the different costs within the total capex in 2012.

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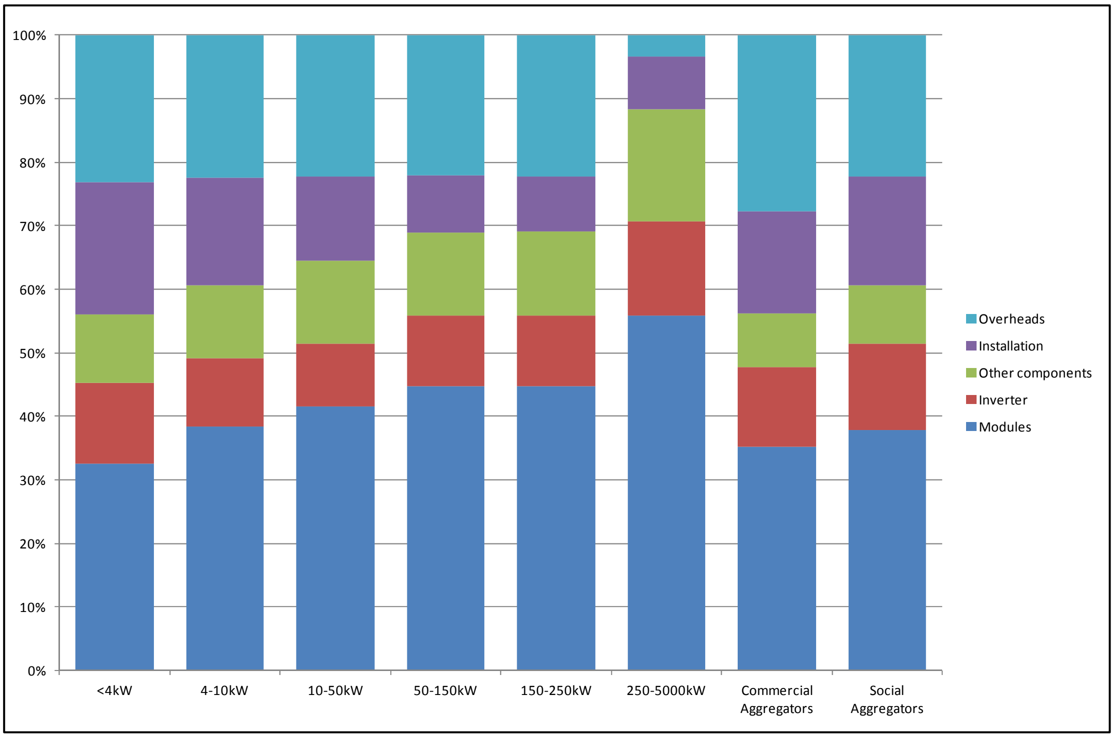
[42] Balance-of-system components are the physical components required for installation. These include mounting structures, fixings, inverters and sometimes batteries.

[43] A learning rate is a calculation showing the decline in unit costs of a generation technology over time or with cumulative deployment (Baziliana et al. 2012).

FIGURE 7.4 SOLAR PV INSTALLATION COST BREAKDOWN



Source: PB, 2012a

As would be expected, the module costs become a more significant factor the larger the installation. This is due to the fixed costs and installation time decreasing per kW under economies of scale. It is difficult to assess the precise role that each of the non-module factors has had in reducing overall installation capex because data varies for each installer/developer and for each installation. But it is clear that collectively the commercial and supply-chain factors are becoming increasingly significant in the capex reductions for solar PV in the UK, and the reductions cannot be singularly explained by module costs (PB, 2012a). The FIT has played a role in reducing the commercial and supply-chain factors by increasing the deployment level of solar PV, and it has brought the benefits of global module cost-reductions to the UK.

Table 7.3 below shows the overall capex each year since 2010. This combines figures from DECC's Comprehensive Review Phase 1 (2011g) and Parson Brinckerhoff's Solar Cost Update[44] (PB, 2012a).

TABLE 7.3 SOLAR PV INSTALLATION COSTS IN THE UK 2010 - 2012

Type of Installation	**Size of installation (kW)**	**Capital Cost of 2010 installation per kW**	**Capital Cost of 2011 installation per kW**	**Capital Cost of 2012 installation per kW**	**% change 2010 - 2012**
Building Mounted	< 4	£5000	£3462	£2564	-49%
	4 – 10	£4545	£2909	£2269	-50%
	10 – 50	£4100	£2700	£2011	-51%
	50 – 150	£4088	£2425	£1885	-54%
	150 - 250	£3805	£2430	£1705	-55%
	250 – 5000	£3805	£2251	£1300	-66%
Standalone	0 - 5000	£3805	£2250	£1300	-66%

Adapted from DECC (2011g) and PB (2012a)

The GB FIT was designed to begin a degression of tariffs from April 2012. This was initially set at 9% to reflect expected reductions in installation capex. Thus, the reduction in solar PV capex of 49 - 66% has far exceeded DECC's expectations and the level of deployment that it has stimulated was not anticipated. However, although the GB FIT is not a major causal factor in the reduction of module costs, it has been significant in driving commercial and supply-chain reductions and solar PV now displays the price reduction effects that transition scholars suggest is a necessary process for the build-up of niche momentum.

SECTION 7.4.3 PRICE-PERFORMANCE IMPROVEMENTS - SUMMARY

As with much of this chapter, and the FIT in general, the focus in this section has been on solar PV. The price-performance improvement, that transition scholars have found to be a necessary process in building niche momentum, is occurring for the solar PV niche alone under the FIT. The scheme has not significantly driven this process for wind, hydro or AD, all of which have only increased capacity modestly. The quote below, from a small-scale RE

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[44] This presents the central estimate within the PB report, which is the median of all the data they have.

financier and investor, illustrates why the pump-priming that the FIT scheme has provided for the solar PV industry is so important in exploring avenues of potential cost reduction.

> *'I think overall the FIT is there to kick-start something and it did have an effect at kick-starting something. It was always the case that you were going to be able to degress quickly because once you had got the ball rolling and got installers, and got capacity in terms of understanding not just how you put these on a roof, because that's not that difficult, but its more the entire system. So how do you do a solar for free if you've got a mortgaged property, how does that work? What do you have to register, do you do it as a licence? When do you need planning permission, how do you go through that. How does VAT work? So all of those things have to be kick-started by there being a bulkhead of market going at it and pushing it, and that happened. And once it does happen the costs go down because you've made your early investment'* (Interview 16).

The scale of deployment that has occurred for solar PV has begun this process of innovating, experimenting and reducing costs and there is evidence of the price-performance improvements required within the analytical framework. Achieving similar reductions in the other FIT niches would require a far higher level of deployment than has occurred so far. The following section analyses the next required niche process identified by transition scholars, the support of a niche by powerful groups.

SECTION 7.5 SUPPORT OF POWERFUL GROUPS

In Section 7.3.3 the financial innovation that has occurred in the solar PV sector was discussed and it was suggested that the increased level of investment interest being shown in solar PV was not only driving development of innovative funding streams and packages but it also represents the manoeuvring of regime actors towards the solar PV niche. This is an important process identified within the transition literature for driving internal niche momentum and it is included in the analytical framework for this study.

SECTION 7.5.1 INVESTORS

As Kern states, '*one of the powerful groups whose support is needed for the development of niches is the investment community*' (Kern, 2012, p. 303). Investors have certainly shown a far higher level of interest in the solar PV space since the introduction of the FIT with finance to drive the majority of the 10,128 commercial installations and approximately 20% of 305,296 domestic installations (61,059) that are aggregated schemes.

It takes some time for investors to evaluate a new technology such as solar PV, but also to understand a new support mechanism such as the FIT. But once investors perceive there to be a good potential for returns then they can start to actively drive the market rather than financing individual schemes. As a solar Business Development Manager explained,

'*The FIT structure took a while to play through but after various analysts and investors have kicked it around for a while and done a few test runs they get a reasonably good sense of where the returns are at each size, and what are the kind of loaded-up returns for the overhead of delivering it. And then the demand starts to move that way and that certainly drags the industry up with it…And then as the market matures you have funds going around looking for projects and they request solar companies to quote against their criteria* ' (Interview 9).

This market development occurred quite rapidly in the ground-mounted sector with solar VCTs and other investors driving the market. But after the fast-track review much of this activity subsided and investors lost money on unfinished projects, abandoned start-up development companies and unused land options (Interview 28). At this stage some investment interest moved to large commercial roof installations but the announcement of a reduction in all solar PV tariffs then halted much of this activity. This was a controversial period for the FIT and a great deal of damage was perceived to be done to investor confidence in the scheme and in DECC more generally (see Table 7.1). The Energy and Climate Change Select Committee, alongside the Environmental Audit Committee, launched an enquiry into the review process, and concluded that –

'*To facilitate the investment in renewables that the country needs, investors need to have confidence in a stable and predictable commercial environment for those investments. The* *scale and pace of the changes now proposed was a shock for the industry and the suddenness of their introduction has damaged investor confidence across the whole energy sector*' (EAC and ECCC, 2011).

An impact of damaging investor confidence is to increase the cost of borrowing and investment. As part of the same enquiry, one large renewables company reported that its cost of borrowing had increased by 5% as a result of the handling of the FIT changes by DECC. This level of increase can stop a project proceeding.

Kern warns against the 'double-edged sword' that influxes of investment can represent. Although an increase in investment is much needed for the development of low-carbon technologies the demands for short-term returns can put huge strain on an establishing sector. For this reason the investment into the solar PV sector is viewed with scepticism by long-term niche actors. The quote below from a Local Authority Energy Manager illustrates this well -

'I often go to the Regen South West conferences and 5 years ago it was very much Local Authority players, a few committed individuals and that was about it. Now there are a lot of lawyers and investment bankers. Unfortunately we have to accept that these people need to be in this market for this to become a fundamental element of the British economy and if you want to become a low carbon economy you've got to have those people in the room. So I suppose it's good that they're there and they're seeing that potential' (Interview 24).

It is not yet clear how the investment community will respond to the changes introduced under the Comprehensive Review of the FIT. But as the quote above illustrates, the opportunity that solar PV provided has encouraged the support of powerful regime groups into the RE space. This support has focused largely on solar PV to date, in part because of the generous returns that were available under the early tariffs. But it is also a result of the low project risks involved in solar PV development. As will be discussed in Chapter 9, the project risks of hydro, wind and AD are more significant which has hindered their development under the FIT. If these risks can be reduced, the solar PV example proves that the support of a regime group such as investors can drive very rapid deployment. The following section explores the increased presence of another regime group, Local Authorities.

SECTION 7.5.2 LOCAL AUTHORITIES

Another powerful group that have responded to the solar PV FIT is Local Authorities (LAs). LAs have access to unique funding streams, low prudential borrowing rates and many large roofs, and are therefore a potentially large player in the PV market. They also hold a unique position to coordinate FIT activity and to facilitate small-scale RE deployment.

In August 2010 the then Secretary of State at DECC, Chris Huhne, lifted a ban on LAs selling power into the market. This allowed the authorities to take advantage of the FIT and install PV on town halls, council homes, leisure centres and other municipal buildings. This opening was perceived by some LAs as a source of income that could be ring-fenced for carbon reduction measures (in particular insulation of council property), by others as an economic regeneration opportunity, and by some as a means of reducing electricity bills and fuel poverty for council housing tenants (Interviews 7, 2 and 26).

Bristol City Council have developed a £1million scheme to install solar PV on schools and Birmingham City Council have developed a £100 million scheme to install solar PV on 10,000 homes across the city (Birmingham Energy Savers, 2012). Schemes such as these have delivered large numbers of installations, although these have been reduced since the Comprehensive Review decreased the tariff and imposed a further reduction of 10% on aggregated schemes. But another role that LAs have in small-scale RE development is coordinating activity. Cornwall Council have been very supportive of the renewable energy sector for the following reasons –

> *'We are reliant on imported electricity and energy, we want to meet our renewable energy targets, Cornwall wants to be clean and Green, it wants to be self-sufficient. It wants those industries to come forward, the jobs, the skills, the education opportunities, and we want solar'* (Interview 2).

The council has worked to develop a database of local suppliers and contractors related to the solar PV industry (Cornwall Solar Directory, 2012), they have organised renewables conferences and meetings that advertise businesses and opportunities in the county (Cornwall Council, 2012b), they have developed renewable energy planning guidance notes for all four renewable FIT technologies which simplifies the permissions process for generators and developers (Cornwall Council, 2012a) and they have a program of renewables education for planning committees in the county who grant permission on planning applications under 5MW. These activities have facilitated FIT deployment in the county and Cornwall's total FIT installations per 10,000 households was 275 against a national average of 104 installations, as of August 2012 (DECC, 2012b). These figures may reflect the considerable resources available in Cornwall but the views of the developers interviewed in this study suggest that the Council's support is instrumental in harnessing those resources. Asked how their experience of dealing with Cornwall Council was, a German solar farm developer stated -

' Beautiful, it's been great. Very supportive, very supportive, beautiful people, great support. It's been great, really, really great. Great support. Nothing that came from Cornwall has been hindering us, all that has been great. What has been hindering us is what has come from London, from DECC' (Interview 11).

LAs are well placed to coordinate small-scale RE activity and as this quote demonstrates developers appreciate the assistance, but some authorities are more involved than others. As the quote below illustrates, from an Energy Consultant working with authorities in London, a lack of targets, powers and resources can harm the impact of LAs -

'FITs and Local Authorities go hand in hand because they're the people that can come in and deliver schemes. Except they can't because they don't have the expertise, the staff, the skills, the access to funds. They're all maxed out, that's what they say anyway, but the vast majority don't have ambitions in that area so the only way they will do it is making it a mandatory requirement to do it. If you do that you have to give them powers. It's all very well having targets but you've got to have powers. But with the RDAs (Regional Development Agencies) *abolished by Eric Pickles* (Secretary of State for Communities and Local Government) *and the national indicator targets gone as well the chasm has got wider and wider and wider'* (Interview 27).

This suggests that although LAs are still a potentially powerful group, able to act as a linchpin in small-scale RE development, they are hindered by a lack of resources and a broader politics stemming from central Government. The previous Labour Government published an Energy White Paper in 2007 stating that LAs had a *'key role to play in* *facilitating the development and uptake of decentralised energy – as community leaders, through their knowledge of local opportunities, and through their powers and responsibilities for planning and regeneration'* (DTI, 2007). The EMR White Paper published by the Coalition Government in 2011 makes no mention of LAs as a delivery body for electricity projects of any kind (DECC, 2011b). It was suggested by several interviewees that despite this reduction of support or power for LAs, they are sometimes effective at promoting and facilitating small-scale RE deployment when one committed individual or small group drives projects through rather than the authority itself. This approach may result in some projects succeeding but it is not replicable and greater coordination is required if LAs are to deliver small-scale RE more consistently.

LAs are a powerful group who have moved into the solar PV space since the introduction of the FIT. They are able to achieve scale due to their access to roof-space but there is inconsistency between different authorities. However the large schemes, such as the Birmingham Energy Savers scheme, are a significant development for the solar PV niche and similar projects in other authorities could build scale quickly and coordinate activity between different actors influencing the sector.

SECTION 7.5.3 ENERGY UTILITIES

The Big 6 energy utilities hold a unique position in the UK electricity system, supplying over 99% of electricity, which gives them direct access to the vast majority of electricity end-users (Ofgem, 2008). They are also very well established companies able to provide, or with access to, large amounts of capital. This affords those companies enormous potential to scale-up novel technologies and to legitimise alternative innovations and they are therefore a very powerful regime group with capacity to be a significant player in the FIT.

The representatives from the Big 6 who were interviewed in this study shared broadly similar views on the FIT scheme. As mandatory FIT licensees they are obliged through their Electricity Supply Licence to register and make FIT payments to eligible generators, although the processing costs are later levelised between suppliers. This processing was viewed to be a burdensome and non-competitive activity for the suppliers, as the quote below from an Energy Consultant working with a number of large and small suppliers -

> *'I think it's fair to say it's had an impact in terms of introducing significant costs in terms of being able to comply with what the licensed suppliers have to do. It's been quite burdensome because it hasn't been implemented well, and then subsequently after its implementation it's now been subject to a number of changes and is likely to be subject to more changes. So it's had a negative impact on the* (supplier) *sector in the round'* (Interview 12).

Interviewees from the Big 6 also stressed the relative insignificance of the FIT against their main generation and supply business and the impression across interviews was that '*given its budget it was almost designed to be unimportant. Small scale renewables on a small scale*' (Interview 22). But despite the broadly negative view of the scheme from the perspective of the large utilities, those companies are also looking to the future and in particular towards smart grids and electrification of the heat and transport sectors. Microgeneration, typically sub 50kW, was viewed by one interviewee who was Head of Retail Regulation at a Big 6 company as a potentially important part of that future system -

> '*One thing this excessive and rather overblown FIT system we've got has done is to stimulate the market and get everybody thinking about it. Somehow we need to get to the next stage, where we can stimulate people through price signals to connect up local microgeneration, some kind of battery storage, ideally electric vehicles or something else run through the battery. Those things are kind of a marriage made in heaven'* (Interview 6).

In this instance the installation of small-scale technologies was not viewed negatively but the implementation and timing of the FIT scheme was seen to be inappropriate. However, the scheme has stimulated considerable interest in solar PV and all of the Big 6 now offer installation options at different scales. A Big 6 interviewee discussed the company's attempts to achieve scale through a number of business models trialled by new entrants, as discussed in Section 7.3.2. These attempts have received increased interest since the German Government announced the phase-out of nuclear power by 2022, in the wake of the nuclear accident at Fukushima, Japan. This event has changed the landscape of generation investment for all utilities and alternative generation options are being considered, including to some degree solar PV and wind (Interview 22).

The impacts of policy risk are hard to gauge because investment decisions and considerations are confidential. However it seems clear that the scale effects that the utilities have brought to the FIT technologies, and specifically solar PV, have been damaged by the handling of the FIT mechanism by DECC. Utilities at that scale invest with a view to maximising their return on capital and although each generation business has its own history with particular technologies they are able to mobilise significant deployment in new technologies. But alternative investment decisions are only taken if the returns outweigh the risk profile and for the FIT technologies, the changes to the scheme have increased the perceived policy risk into the future. The FIT is only just over two years old and so it is still unclear exactly how the large utilities will respond to the opportunities it presents, particularly for the technologies with longer lead times such as wind and hydro. But despite a broadly negative view towards the mechanism itself, the FIT has increased utility activity in the small-scale RE sector.

SECTION 7.5.4 SUPPORT OF POWERFUL GROUPS SUMMARY

A number of powerful groups have responded to the introduction of the FIT and have shown considerable interest in the opportunities the scheme provides. There has been an influx of investors into the solar PV space which has driven rapid deployment but is also partly responsible for the boom-and-bust trend which has characterised the last two years for the sector. Investors have also been badly affected by the changes to the FIT scheme, and the way the tariff reductions were introduced has raised the risk profile for solar PV investment and perhaps for all RE projects.

Another powerful group active in solar PV has been LAs who have started to deliver large aggregated schemes and have the capacity to add much more. They are also a potentially central actor in small-scale RE development due to their unique ability to coordinate activity, as illustrated by Cornwall Council. However, there is inconsistency between different authorities and progressive work is often a result of committed individuals and small groups.

The electricity utilities have also moved into the solar PV space to varying degrees. All of the Big 6 companies have installation businesses but the common view is one of scepticism towards the FIT timing and design, but of interest in the technologies for the future.

The FIT has certainly encouraged powerful groups to enter the small-scale RE sector and this has been a significant development in advancing the solar PV niche. There is a far broader understanding of solar PV as a technology and an asset class and the cost reductions that have occurred since the FIT was introduced have further legitimised the technology. But PV still requires substantial support to remain viable and the powerful groups who have entered the space are therefore reliant on the FIT. The handling of the FIT by DECC has threatened the continued presence of those groups in the sector and it remains to be seen how they will respond to the most recent changes to the scheme.

SECTION 7.6 CHAPTER SUMMARY

This thesis is exploring the niche, regime and landscape aspects affecting the FIT in order to identify the role that the scheme is having in electricity system transition. This chapter has focused on the niche level. It has shown that the FIT has been a very significant policy mechanism for the small-scale RE sector. In particular, the solar PV niche has developed hugely since the scheme was introduced which has resulted in a high deployment rate but also there is evidence of learning processes, price-performance improvements and support from powerful groups and the thesis therefore argues that momentum is building for this technology-niche. But the degree to which it could challenge the existing dominant electricity configuration depends on the stability of the regime itself. This is explored in the next chapter.

The costs of solar PV have fallen dramatically since 2010, driven largely by a global reduction in module prices but also affected by the commercial and supply-chain development that the GB FIT has stimulated. It is difficult to quantify the weighting of each factor in the reduction of PV installation costs but the non-module factors, that are more directly driven by the FIT, are likely to have a significant role going forwards as the module price begins to stabilise as predicted (PB, 2012a). The price-performance improvements that are a requirement of niche momentum have clearly occurred for solar PV.

There is also evidence of powerful actors moving into the solar PV space although they are all sensitive to changes to the support provided. The presence of investors, Local Authorities and energy utilities in the PV space suggests that the niche is developing rapidly but its future depends on the continued support of these groups.

The FIT has provided the platform for commercial and financial innovation and has brought some technological innovation to the UK. This has had a significant role in driving solar PV deployment and in developing the sector. The changes to the FIT have impacted on this innovation in the short-term, mainly by increasing the risk associated with the scheme (discussed further in Chapter 8), but this thesis argues that the learning processes that have been demonstrated have created a foundation for further development in the long-term. These processes were not occurring before the FIT was introduced and the scheme is therefore a driver of niche momentum; a process that is central to transition.

The other three non-PV niches have not seen the same degree of learning, price reduction, or powerful support due largely to the low deployment rates for these technologies. Wind, hydro and AD capex is predicted to flat-line over the next few years. The reasons for the low deployment rates are explored in more detail in Chapter 9.

The next chapter analyses the developments within the regime that have been driven by, or are affecting, the FIT and it looks at the landscape processes related to the FIT and evaluates the impact they have had.

Chapter 8 Analysis of the Interaction between the GB Feed-in Tariff, the Existing Electricity System and the Wider Context

SECTION 8.1 CHAPTER INTRODUCTION

This chapter analyses the regime and landscape processes relating to the FIT and discusses the interaction of all three levels identified in the analytical framework; niche, regime and landscape (see Figure 4.2). Section 8.2 analyses the impacts the FIT scheme has had on the electricity regime, and the changes occurring within the regime that are affecting the FIT. Section 8.3 explores the landscape processes that are affecting the FIT. These sections directly addresses Secondary Research Question 3 -

- How is the current electricity system responding to the FIT and what impacts are political, economic and socio-cultural developments having on this response?

Section 8.4 brings together the analysis of the niche, regime and landscape levels and discusses the *interaction* between all three. This interaction is central to understanding the broad processes of change occurring in the electricity system and what role the FIT has within them.

SECTION 8.2 REGIME DEVELOPMENTS UNDER THE FIT

This section addresses the regime processes that are related to the FIT. Again, solar PV and the impacts that it has had is the main focus of the analysis due to its dominance of the FIT installations. The analysis is structured by the three processes identified in the analytical framework – changes in rules (Section 8.2.1), technologies (Section 8.2.2) and social networks (Section 8.2.3) (see Figure 8.1 below).

FIGURE 8.1 REGIME PROCESSES

SECTION 8.2.1 CHANGES IN COGNITIVE AND REGULATIVE RULES

Cognitive rules are defined here as the shared belief systems held by actors within the regime. Although individual actors have different beliefs, there are certain shared ideas that emerged from the interviews and industry literature that characterise the regime. Regulative rules are the laws, standards and guidance under which the electricity system operates.

The Energy and Climate Change Select Committee, who have scrutinised the EMR Energy Bill and DECC's overall strategy, argue that DECC are overly concerned with supply-side capacity-adding technologies and that they are '*still failing to give enough priority to ensuring that demand-side measures contribute to our energy policy goals*' (ECCC, 2011). This supply-side focus is a very significant cognitive rule underpinning electricity policy that has driven sector development over the long-term (Interview 26). This thesis argues that because the industry is dominated by large vertically integrated companies, the principal incentive has been to drive down the costs of generation in order to *stimulate* demand and increase profits across the business. But solar PV, wind, hydro and AD under 5MW do not fit well into this cognitive view because they provide capacity in small, diverse generation plant which have relatively low load factors and are currently more expensive than marginal gas CCGT. This is illustrated well below -

'To be frank, I think that if we're going to decarbonise the sector, and it has an additional cost above business-as-usual, there's quite a strong case to be made for not supporting small scale generation at all because in terms of cost per MW you'd probably just put up big wind farms. Because PV out there as £400 per MW as a subsidy, that's an awful lot for something that only works half the day and doesn't coincide with peak demand, so it

doesn't do anything to delay stress on the networks. So if customers are being asked to pay for that, people have said scrap the FIT, we never should have done it in the first place. It was only ever going to deliver 2% towards our renewables target and probably cost 10 times what it would have cost if you'd just done it on big scale stuff. So what are you playing at? (Interview 12).

This is a very reasonable argument if the FIT is viewed from the regime perspective focused on capacity. In terms of delivering renewable capacity the FIT figures are insignificant and the technologies are expensive. But if the FIT scheme is viewed as a policy designed to commercialise alternative technologies then, for solar PV, it has been very effective because the installation rate has increased enormously and the installation costs have sharply reduced. Equally, if the scheme is viewed as a mechanism to pump-prime the industry then again, for solar PV, it has delivered, as Chapter 7 explored. Evaluating the success of a renewable support mechanism rests on ones view of what it is designed to achieve and also what wider electricity policy is working towards. The Renewables Roadmap states that –

'*Our goal in the medium to long term is to help renewables compete on a level playing field against other low carbon technologies*' (DECC, 2011h, p.19).

But this overarching goal of renewables policy is challenging to the cognitive rules of the regime because it may not deliver significant capacity now. Also, the capacity it does deliver will come from a diversity of scales and locations making management of the network more complicated than under a centralised system built mostly around large, flexible thermal plant.

It is unlikely that the cognitive rules of the regime, prioritising capacity additions and large-scale technologies, will change in favour of small-scale RE until it becomes competitive with conventional generation options. This will require continued regulatory assistance. There are at present a number of regulatory drivers of change placing pressure on the existing regime such as the EU ETS, the UK-specific Carbon price floor, and the Large Combustion Plant Directive. Also Ofgem, the energy regulator, now has a specific objective to contribute to the achievement of sustainable development and they state that '*encouraging sustainable development through reduced carbon emissions is a key policy objective for Government. Distributed energy could make an important contribution to this and other* *goals, including security of supply and alleviating fuel poverty* (Ofgem, 2008, p. 2). There is on-going work to address the barriers to distributed/decentralised energy, of which the FIT technologies are a part. Many of these barriers remain but the FIT scheme is itself a minor change to the regulatory environment by mandating suppliers to offtake FIT generation and make the tariff payments.

The FIT scheme is not shifting the regulatory environment by itself but there is a developing body of regulation that is starting to increase pressure on the regime, of which the FIT is a part. An interviewee from one of the Big 6 indicated the impact that this build-up of regulation has had on their strategy –

> ‘*Looking at* (the company) *on a European scale, 5 years ago we were building coal power stations in Europe and now we’re not. I think that tells you how significant regulatory changes can be. I would be amazed if anyone in the electricity industry hasn’t had to change their business model*’ (Interview 22).

SECTION 8.2.1.1 COGNITIVE AND REGULATIVE RULES SUMMARY

The electricity system is in a period of transition. There is a build-up of regulation that is placing pressure on the regime to change, and due to the need to upgrade much of the existing generation and network infrastructure the system is in a state of flux. However, the cognitive rules that govern the response to the perceived instability of the regime are still capacity-centric. Electricity policy is highly politicised and decisions are taken within a broad context of influencing factors. The FIT has promoted the supported technologies, in particular solar PV, as viable options within the generation mix but the costs of these technologies above marginal gas plant are still a barrier to their uptake. If the costs of small-scale RE reduce further or the marginal cost of power increases then the cognitive rules may change but the regulatory framework that exists at present is not sufficient to instigate this.

The following section looks at the technologies within the current regime and analyses the impact that the FIT, and small-scale RE, is having within that.

SECTION 8.2.2 CHANGES IN TECHNOLOGIES

Section 2.2 of Chapter 2 discusses the physical infrastructure that characterises the existing electricity regime in the UK. It explains how that infrastructure is locked-in to its current centralised configuration and the rest of the Chapter details how the other system components act to maintain this lock-in. This section looks more specifically for any signs of change within the regime and it analyses the impacts that the FIT has had within that context.

The electricity regime in the UK is dominated by large-scale, centralised generating technologies, the majority of which are coal- or gas- fired (see Figure 2.1). But solar PV is beginning to achieve significant scale in the UK and across Europe. For the first time, in 2011 solar PV was the primary generation technology in Europe in terms of added installed capacity. 21.9 GW was connected to the grid[45], which outpaced both gas and wind installation, both just below 10 GW installed. According to the European Photovoltaic Industry Association, this equates to enough generated electricity to compensate for the closure of all the German nuclear plant in the same year (EPIA, 2012). Between 2000 and 2011 gas, wind and solar PV were the three principal technologies added to the system in Europe (see Figure 8.2 below).

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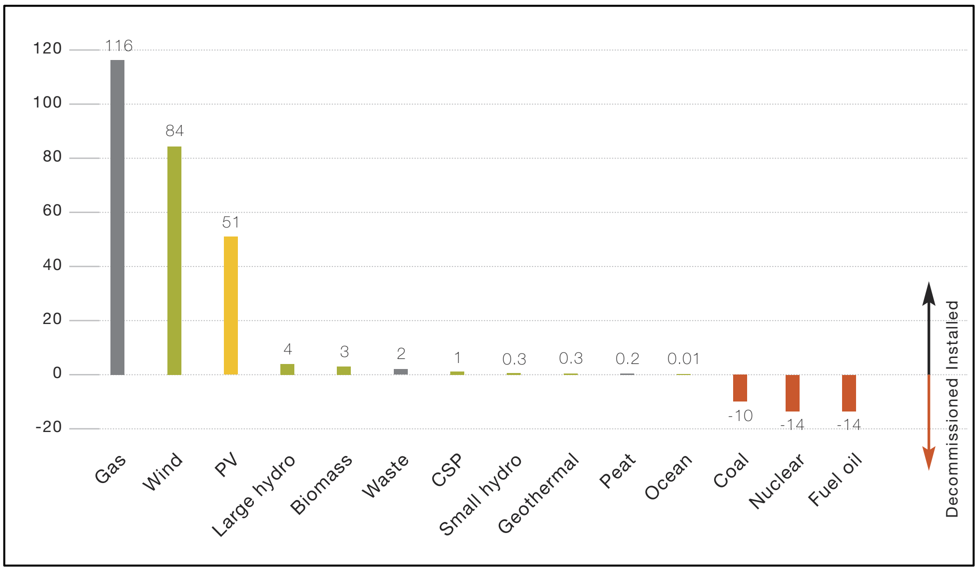
[45] 10MW was decommissioned (EPIA, 2012).

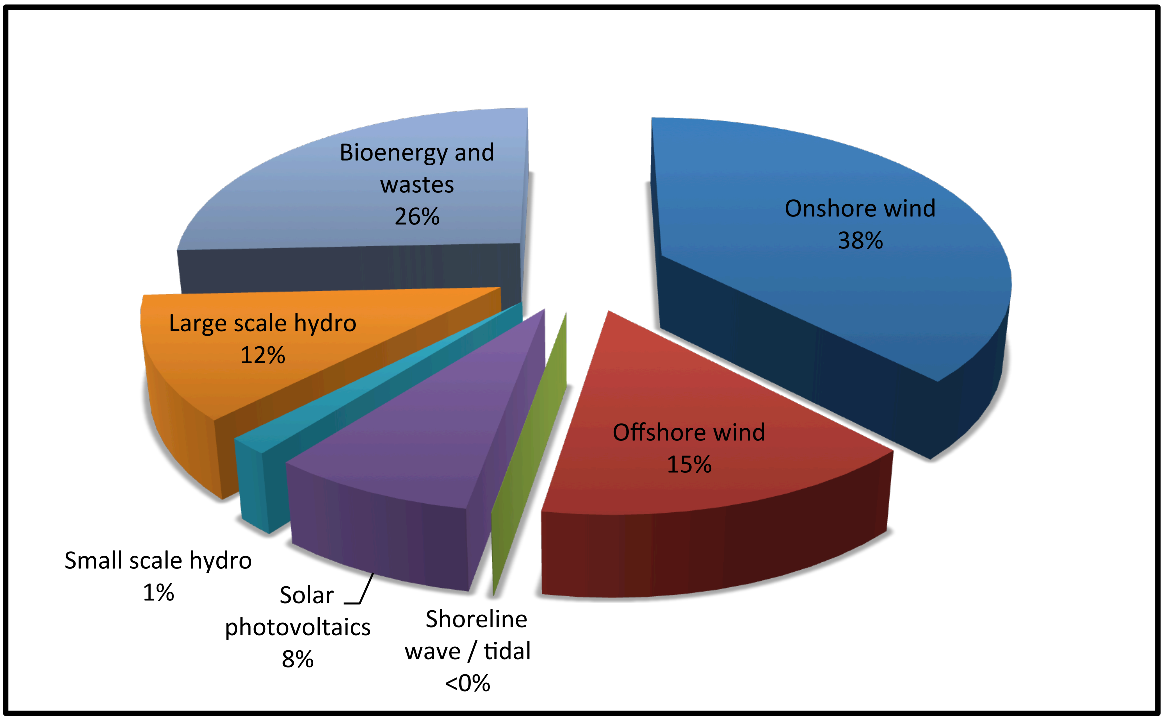
FIGURE 8.2 NET GENERATION CAPACITY ADDED IN THE EU27 FROM 2000 - 2011



Source: EPIA, 2012

In the UK 1.4GW of renewable capacity had been installed under the FIT by 31 August 2012, 1.27GW of which was solar PV. The total capacity of grid-connected power in the UK was 89.1 GW in 2011 and the combined capacity supported under the RO was 8.5GW (DECC, 2012i). Solar PV is a relatively small proportion of the totals but it is notable, largely because it has increased so rapidly. As Figure 8.3 shows, as a proportion of total RE capacity it has increased to 8%. It is important to note however, that solar PV has a low load factor of approximately 10 - 15% depending on location so the generation figures would be far lower (PB, 2011).

FIGURE 8.3 CAPACITY OF ELECTRICITY GENERATED FROM RENEWABLE SOURCES, AS OF JULY 2012.



Source: DECC 2012j

Figure 8.4 below shows the commissioned and decommissioned capacity in the UK between 2007 and 2011[46]. The commissioned plant has all been renewables and CCGT with a clear trend of decommissioning conventional coal and nuclear plant. Also, it is important to note that the renewables figures in Figure 8.4 are 'Declared Net Capacity' (DNC), adjusted to account for the intermittency of the various technologies. DNC is defined as '*the maximum continuous rating of the generating sets in the stations, less the power consumed by the plant itself, and reduced by a specified factor to take into account the intermittent nature of the energy source… DNC represents the nominal maximum capability of a generating set to supply electricity to consumers* (DECC, 2012j, p. 178). Small-scale hydro, wind and solar PV capacity has been calculated by multiplying by factors of 0.365, 0.43 and 0.17 respectively (DECC, 2012j).

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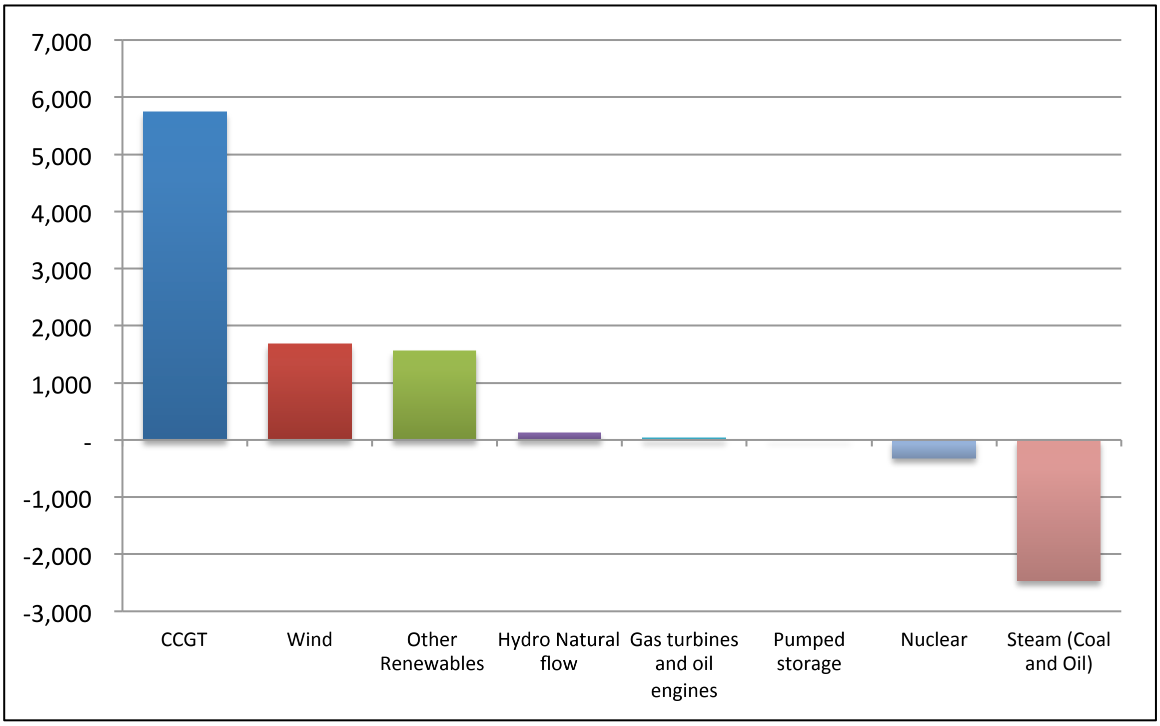
[46] A range of years was chosen in order to avoid single plant closures distorting the trend.

FIGURE 8.4 UK PLANT CAPACITY CHANGES BY TECHNOLOGY 2007 - 2011 (MW)



Adapted from DECC, 2012i and DECC, 2012j

Between 2010 and 2011 CCGT capacity reduced by 1541 MW due to the closures of Teesside and Fife power stations. In this period renewables were the only additional capacity in the UK with solar PV contributing 150 MW or 20.2% of that total (which includes a reduction of 83% to account for the load factor) (DECC, 2011d). For an industry that had delivered just 2300 installations by the end of 2007 these are striking figures (Bergman and Eyre, 2011). This thesis argues that the solar PV installation figures, and therefore the FIT, are changing the technological configuration of the electricity regime. The vast majority of generation capacity is still large-scale but the speed with which solar PV capacity has been added since 2010 is a significant development and if deployment was to continue at the same rate PV would become an established regime technology.

Despite the high level of additional solar PV capacity the FIT has delivered, it has not yet been disruptive to the network. An interviewee from a DNO operating in the South of England suggested that there were, as yet, no adverse effects on the distribution network from FIT installations and that the DNO's could deal with far higher levels of domestic solar PV (sub 4kW) before they had significant issues. At present the DNO's, and suppliers, operate a policy of ‘Fit and Forget’ whereby installations are recorded but any exported power is allowed to just spill onto the network. Due to the radial nature of the distribution network any exported power from a domestic installation would appear to the DNO, or system operator, as a drop in demand on the network. They do not have sufficient visibility at that level to know what has reduced the demand (Interview 22 and 4). However, the DNO interviewee did discuss the likelihood that in the future DNO’s will have to start actively managing the distribution network as the penetration of small-scale electricity and heat technologies increases. But they explained that the current deployment levels do not require this input (Interview 31).

In the UK, the capacity of solar PV is not yet sufficient to significantly influence the wholesale power market but in more mature markets such as Germany or Italy it has had an effect. The marginal cost of renewable technologies that have no fuel input (e.g. wind, solar, wave) is effectively zero because there are no fuel costs[47]. Other generation plant such as coal and CCGT stations have a marginal cost that is linked closely with their fuel costs. In a pure electricity market the renewable power would be taken first because it has the lowest marginal cost. The impact of an increasing proportion of renewable generation is that power is taken from the other generators at a higher and higher level of demand. Assuming actual demand remains constant, this lowers the marginal cost of electricity and negatively affects the profitability of other generators. This is known as the merit-order effect (Bode and Groscurth, 2010). Both the German and Spanish markets have experienced a reduction in wholesale prices as a result of this (de Miera et al. 2008). In addition, in the case of solar PV, when output is at its highest a degree of that output will be used at source (e.g. within the building on which the PV is mounted). This lowers overall demand from the network and thus further reduces the profitability of conventional plant during these periods.

However, there are many factors influencing the wholesale markets that could counteract the two impacts discussed above. Location, grid capacity and existing contracts will often influence what generation is taken and what is constrained, spilled or paid not to generate. Also, although the marginal cost of some renewables is close to zero, the capital costs are

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[47] There are operation and maintenance costs associated with renewable technologies which would be included in the marginal cost. However these are relatively low compared to fuel costs for non-renewable technologies.

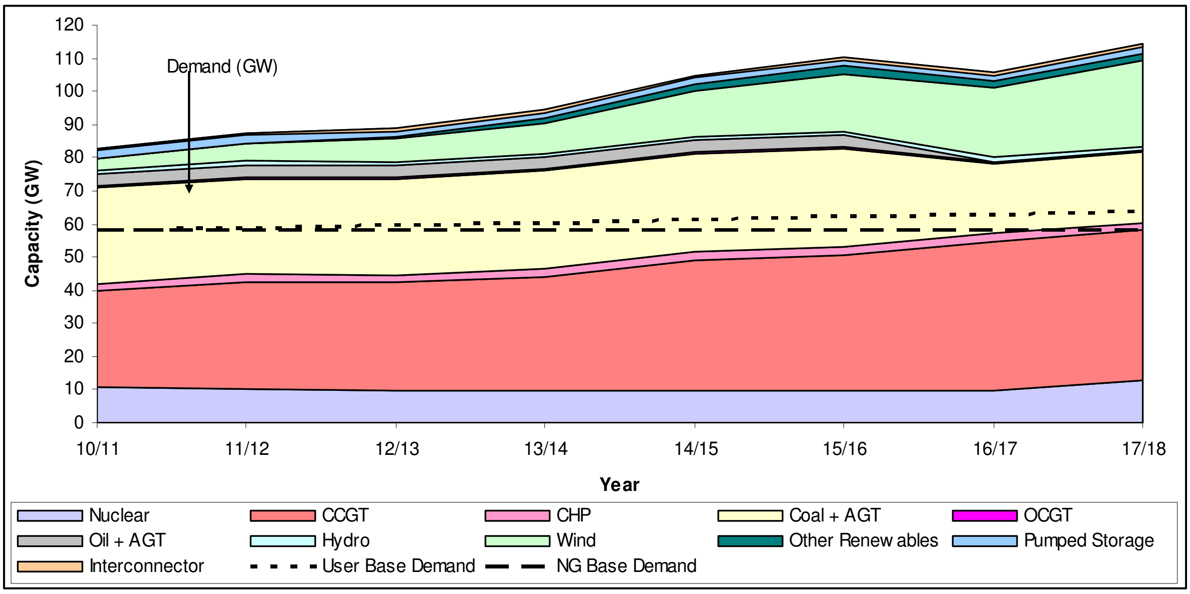
high and depending on the support mechanism in place for that technology, there is an associated cost of generation for the end-user (Bode and Groscurth, 2008). Each country has a unique electricity market and regulatory framework that will influence the impact of renewable generation and it is beyond the focus of this research to predict what impact future solar PV, and RE, deployment will have on the UK power markets. But it is clear that an increasing proportion of renewable capacity will have multiple impacts on the economics of electricity (Green and Vasilakos, 2011).

The FIT has not yet delivered a level of solar PV capacity that would significantly affect the power markets in the UK. Germany had approximately 25GW and Italy had 13GW of PV in 2011 so the impact on these markets is far greater (EPIA, 2012). But a more important development for the UK electricity system is the huge number of new generators. There were 216,021 generators and 315,424 installations supported under the scheme at the end of August 2012 which is a dramatic influx of stakeholders into the system. This is discussed in the following section.

SECTION 8.2.2.1 CHANGES IN TECHNOLOGIES SUMMARY

Section 8.2.2 has shown that solar PV across Europe is achieving considerable scale. This has had an impact on the power markets in Germany and Italy and it is starting to influence the economics of conventional generation. In the UK, the FIT has delivered a notable level of capacity in a short time and solar PV accounted for 20.2% of additional capacity between 2010 and 2011 (which includes a reduction of 83% to account for the load factor). The growth in PV is affecting the technological configuration of the regime to a degree but is not yet at a level to affect the distribution network or the power markets. Figure 8.5 below shows the capacity that National Grid expect to come online up to 2018. The additions in this picture are mostly increases in wind (predominantly large-scale onshore and offshore) and CCGT's and a small increase in nuclear. The "Other Renewables" capacity, which includes solar PV, does increase but it is still very marginal to the large-scale technologies of the regime.

FIGURE 8.5 NATIONAL GRID PREDICTED CAPACITY TO 2018



Source: National Grid, 2011

SECTION 8.2.3 CHANGES IN SOCIAL NETWORKS

The social networks that characterise the electricity regime are '*large and stable, because actors have aligned their activities*' (Geels and Schot, 2007, p.403). But as discussed in Chapter 7 Section 7.3.2, new entrants are often the source of disruptive, progressive innovation and they can change the course of unsustainable regime practices (Hockerts and Wustenhagen, 2010). But the stability of the existing networks is a part of the lock-in of the regime and it has been argued that attracting new generators, developers, investors, aggregators, and suppliers into the electricity regime is a requirement for the transition to a sustainable low-carbon system (Mitchell, 2008, Geels, 2004, Geels and Raven, 2006). This section evaluates the degree to which the FIT has stimulated that change in the social networks of the regime.

Certainly the 216,021 new generators brought into the electricity system under the support of the FIT represent a development in the electricity sector. As the previous section showed, in terms of capacity the FIT technologies are marginal but the number of new stakeholders in the system is dramatic. In addition, the FIT has encouraged many installers and developers to enter the small-scale RE space, and particularly solar PV. The number of jobs in the PV sector was reported by the REA (Renewable Energy Association) to be 25,000, although this may have reduced since their report was published and the installation rate has slowed (see Chapter 6 Section 6.3.1) (REA, 2012). The vast majority of these jobs have resulted from the demand stimulated by the FIT. There is no employment data for sub 5MW wind but there are approximately 800 people employed in the sub 50kW sector and employment in the wind industry as a whole is growing by 15.7% annually (RenewableUK, 2012; PB, 2012b). The small-scale RE sector is clearly expanding under the support of the FIT and the new entrants that the scheme has encouraged are interacting with regime actors such as the DNO's, Ofgem, investors and suppliers.

New entrants were viewed with caution by the majority of the established regime actors interviewed for this study. An established wind developer argued that new entrants in the wind sector tended to rush into projects without understanding the sensitivity of local communities and landowners to planning applications. This had damaged the reputation of the industry as a whole and had harmed the prospects of developing in certain areas (Interview 29). Also, a number of interviewees discussed the impact that an influx of new investors had had on the solar PV space. Many of these investors were looking to make quick investments, particularly in ground-mounted solar, but had no intention of remaining in the industry over the long-term. This was seen to be damaging for the industry because it responded to the demand driven by investors by scaling-up too quickly. But when the FIT changes began, most of the investment disappeared and the developers, contractors and installers were stranded. This is illustrated below –

'*I set up the renewables company last year (2010) to deliver and build renewable schemes. There were two of us but in January when we took on the third person we got the 200 million pounds (from a solar PV VCT). The idea was we were moving to a new office, we were going to buy 3 companies, we had in those 3 companies 75 staff, it was all set to go and we were going to start building elsewhere. We actually went very big very quickly. But after the (fast-track review) announcement all that went off the table overnight*' (Interview 3).

The bubble created by the generous returns for solar PV was difficult for the industry to navigate and it damaged the reputation of the sector within the regime. It was suggested that the sector now requires funds that are capitalised for the long-term. New sources of finance are required for this, as are new entrant developers to build it out, but a longer term perspective is required if the industry is to grow sustainably. If it is able to do this then it might start to challenge the regime more profoundly (Interview 16).

A barrier to attracting long-term funds to a sector is the perceived risk of innovative projects or companies failing to deliver on an investment. But as successful projects are completed and a market matures the legitimacy of a new technology or company improves. HomeSun is a company that entered the solar PV market using the new aggregator business model and have now delivered 23MW of installations. In August 2012 the whole portfolio was sold to Aviva Investments in the largest ever rooftop solar deal in the UK (Business Green, 2012). Developments such as this establish solar PV as an asset class and they consequently legitimise the sector within the practices of the regime. It is difficult to gauge the impact this has on the social networks that exist but the more successful schemes that are financed, developed and sold, the more legitimate new entrants are likely to become.

SECTION 8.2.3.1 CHANGES IN SOCIAL NETWORKS SUMMARY

The general view expressed by regime actors was that the FIT is burdensome and too fragmented for the capacity it delivers. However, it has introduced many new actors to the electricity system and the FIT-supported small-scale RE sector is predicted to keep growing (PB, 2012b). This will have an increasing impact on the established social networks in the electricity regime as actors become more accustomed to dealing with a wider variety of stakeholders. But it is difficult to evaluate the impacts that the FIT is having on the social networks of the electricity regime now because the whole industry is in a period of uncertainty. Electricity policy is highly polticised at present due to a number of interrelated landscape factors. The FIT is still a very recent development within this context and the degree to which the scheme influences the existing social networks depends on wider political and economic factors. These landscape factors are explored in the Section 8.3.

SECTION 8.3 LANDSCAPE DEVELOPMENTS AFFECTING THE FIT

The electricity landscape describes the overarching, structuring context for the electricity system. The landscape concept used here focuses on macro-political developments, macro-economic trends and socio-cultural practices (see Figure 8.6).

FIGURE 8.6 LANDSCAPE PROCESSES

Each of these elements is explored in turn to identify the influence that they have had, or may have in the future, on the FIT niches. The broad politico-economic context that frames electricity policy in the UK is discussed in Chapters 1 and 2 and this section avoids repeating that background. Rather, the analysis presented here considers the factors that impact on the FIT specifically. It is important to note that the FIT was only introduced two and half years ago and landscape developments are typically slow-moving. Therefore the analysis does not evaluate the landscape developments that have occurred since the FIT was introduced but it presents an interpretation of the causal effect of long-running and relevant landscape developments on the scheme.

SECTION 8.3.1 MACRO-POLTICAL DEVELOPMENTS

The prevailing macro-political context for all socio-technical systems in the UK is centred around economic growth and globalised, liberalised markets. The capacity for markets to deliver the most efficient outcome is a pervasive and deep-rooted landscape feature. In the UK, regulation is used to steer markets and market-actors in a loosely defined direction, but also to act where market imperfections exist (e.g. climate change) (Mitchell, 2008). The electricity system fits very much within this wider political context with a privatised industry, regulated wholesale and retail markets, and the regulator Ofgem.

But the macro-political context affecting the electricity system has been destabilised by two landscape developments that have become increasingly prominent in recent years. Climate change and energy security concerns are challenging the suitability of the existing electricity regime and they are questioning the capacity for solutions to be found within the existing political framework (Kuzemko, 2009; Shackley and Green, 2007). Of particular relevance to the FIT is the political response to climate change.

The Climate Change Act (2008) committed the UK to reducing carbon emissions by 80% by 2050. The same act created the CCC who advise Government on meeting their climate targets. The CCC recommended that meeting the 2050 target will require the electricity sector to decarbonise by 2030 to allow more time for the greater challenge of decarbonising the heat and transport sectors (see Chapter 1 Section 1.3) (2011b). It is currently being debated whether the 2030 decarbonisation target should be added into the 2012 Energy Bill as an ammendment, but it has already influenced the politics of electricity and it is framing debates about generation options (ECCC, 2011). In addition, the EU 20:20:20 renewable energy target of 15% by 2020 translates to a 30% target for the electricity sector (DECC, 2011d). The FIT was introduced into this context with an objective to '*contribute to meeting our challenging carbon reduction and renewable energy generation targets*' (DECC, 2010a, p. 9).

The FIT has been running alongside the Electricity Market Reform consultation process which has highly politicised electricity decision-making. The role of nuclear, natural gas, unconventional gas, CCS, coal, and RE generation has been widely debated and the consultation process has incited rather than settled disagreement (ECCC, 2011). As will be discussed in the next section, the passage of the Energy Bill has also coincided with a complex debate over the rising costs of electricity bills. In addition, there has been a debate between DECC and Treasury over various aspects of energy policy including, notably, the support levels for wind and the future role of gas (Ernst and Young, 2012).

The impact of these developments on the FIT is related to the perceived lack of political certainty and direction from Government. The quote below illustrates this -

> *'The lack of clarity and detail across the various policy announcements, and the ambiguous messages coming out of the Treasury and the Department of Energy and Climate*

Change, have been frustrating for the renewables sector. The ongoing uncertainty risks delaying the development of the sector, and in particular, the achievement of the UK's 2020 target' (Ernst and Young, 2012, p.27).

For a homeowner considering a solar PV installation, the political uncertainty surrounding RE may seem quite removed. But for a wind developer seeking to raise finance on a project with a two year lead-time, the intentions of Government are critical because the support the project receives may change before it is developed. Every interviewee working towards developing, installing, financing or planning FIT projects stressed the importance of a stable, coherent political framework. The quote below demonstrates this -

'Financiers and developers will always be better at innovating if you've got a stable platform, and you can actually build something on that stability. If you've got a rocking platform you've just got people dancing around and you can't really build very much on top of it. That volatility is the enemy of innovation' (Interview 16).

The FIT, and the whole electricity system, is influenced by a complex macro-political context. This context is referred to throughout this thesis and particularly in Chapters 1 and 2. Of importance here is the degree to which the FIT is buffeted by wider political events. The four FIT niches addressed in this research are dependant on the continued support provided by the scheme and the industries that surround them are vulnerable to any changes to that support that result from political developments.

SECTION 8.3.2 SOCIO-CULTURAL FACTORS

An important socio-cultural factor framing the electricity system is a context of passive energy consumers who receive and pay for power supplied by a large utility in a unidirectional relationship. One of the aspirations of privatisation was that energy users would be empowered to become "utility maximisers" who would shop-around between competing companies (Shackley and Green, 2007). But the Big 6 companies that control approximately 99% of supply in the UK sell a standard product and the tariffs that they offer have been criticised for confusing customers rather than empowering them to engage (Ofgem, 2012c).

One of the objectives of the FIT scheme is to engage individuals in the electricity system and in the low-carbon transition –

> *'Engagement and investment, driven by the FITs, will help to...bring a greater number of individuals into everyday contact with electricity generation technologies. We believe this greater contact will lead to greater understanding of electricity and energy issues, which could lead to additional energy saving efforts across Great Britain'* (DECC, 2010a, p.9).

The degree to which the FIT has achieved this objective is difficult to gauge because it is likely to be a long process. As stated above in Section 8.1.3 the 216,021 new generators introduced under the FIT is a significant development for the electricity sector and it will have an impact on the socio-cultural practices of those generators. But the behavioural impacts of microgeneration technologies, and RE in general, are relatively unknown. Studies by Dobbyn and Thomas (2005), Keirstead (2007) and a joint report between the Cabinet Office, DECC and the Department for Communities and Local Government (Cabinet Office et al. 2011) indicate that a positive behavioural response can be achieved. But Shackley and Green (2007) also warn of the potential for a rebound effect where domestic generators increase their energy use in the home, or within another area of the economy (e.g. air travel), as a result of the perceived benefit of the renewable technology.

It is unclear how successful the FIT has been, or will be, at positively influencing the socio-cultural context of electricity. But those socio-cultural patterns are deeply ingrained and driven by wider trends of consumption and individualisation linked to the macro-political and macro-economic contexts (Shackley and Green, 2007). Change at this landscape level is inherently slow but at present the socio-cultural trends are not creating a specific opportunity for alternative generation options or destabilising the electricity regime. In fact, the patterns of energy use that these trends encourage may be one of the greatest barriers to a low-carbon transition because end-users have been passive consumers in the electricity system for so long. Those end-users may have to become more engaged in practices such as demand side management if intermittent RE is going to be a significant part of the future system. The role of the FIT as an agent of change in the socio-cultural context is not yet known because the scheme is still a recent development.

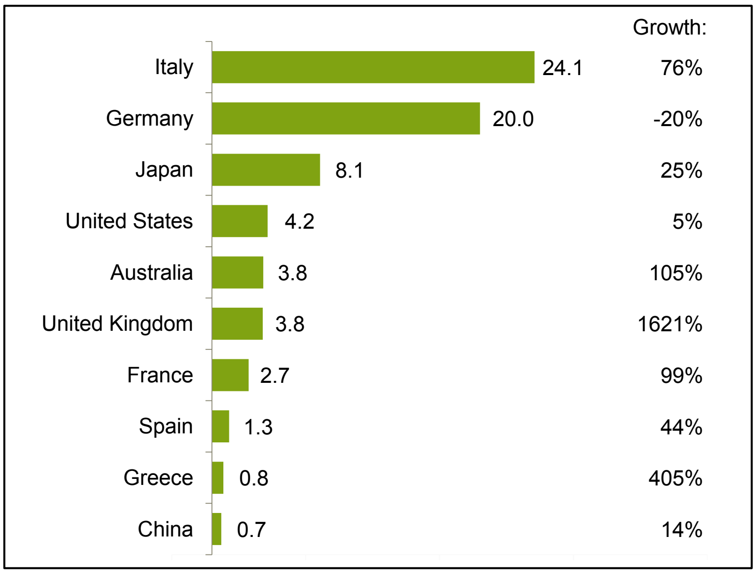
The following section addresses the macro-economic context surrounding the FIT.

SECTION 8.3.3 MACRO-ECONOMIC TRENDS

The macro-economic context that has influenced the FIT is dominated by the fallout from the financial crisis of 2008 and the recession of the UK economy. The political response to the crisis has created a challenging investment environment and it has also driven a number of socio-economic trends. This has influenced the FIT in a number of ways.

1. As part of a wider program of public spending cuts the UK Government introduced a Control Framework for levy-funded spending in October 2010 which placed a cap on the FIT budget up to 2014/2015 (DECC, 2011). This was initially set at £867 million and later increased to £1,064 million. As discussed in Chapter 5 Section 5.8.1, this changed the basis of the FIT design by introducing a volume risk that would increase with deployment. The limits to the budget were used as justification for the severity of the cuts to the solar PV tariffs (DECC, 2011e).
2. In general, raising finance has been more challenging. Access to debt finance has been particularly tight meaning there has been a higher proportion of equity investment in all RE projects (Interview 28). But despite the challenging environment the clean energy sector has been one of the few areas of growth in the wider economy (BNEF, 2012). The figure below illustrates the investment in sub 1MW solar PV in 2011 for the top ten countries globally and it also shows the growth on 2010.

FIGURE 8.7 SOLAR PV INVESTMENT BY COUNTRY ($BN) AND GROWTH ON 2010



Source: BNEF 2012

The UK is still behind the largest investors but its market has clearly grown far faster than any other in this list with a 16-fold increase in one year. This partly reflects the unsustainable peak in installations created by the proposed December cut-off date for sub 50kW solar PV tariffs. But it also shows a degree of insulation of the solar PV/FIT market from the rest of the economy. Despite the challenging economic conditions investment in PV is relatively strong (BNEF, 2012). As discussed in Chapter 6, the economic conditions have also depressed interest rates which could be a factor explaining the high uptake of FIT-supported solar PV.

3. The macro-economic context has impacted on the economic position of households in the UK, and on average energy expenditure as a proportion of household expenditure has increased in real terms every quarter since the start of 2010 (ONS, 2012). As a result the retail energy market has become highly politicised and any increases in retail prices are heavily scrutinised. Energy bills have continued to increase but the CCC estimate that 84% of this is unrelated to low carbon measures (CCC, 2011b). The predominant factor in these increases is the rise in the wholesale price of gas but low carbon measures that are funded by a levy on fuel bills, such as the FIT, have been highlighted in the British media (CCC, 2011b). This places pressure on Government to reduce the support given to low carbon technologies which has

> created tension between Treasury and DECC and increased the perceived uncertainty surrounding the FIT and other schemes (EAC and ECCC, 2011).

In summary, the macro-economic conditions that have surrounded the FIT since its introduction in 2010 have been challenging and they have had both negative and positive impacts on the FIT-related small-scale RE sector. Tighter spending controls in Government have decreased the stability of the FIT and introduced an additional risk to FIT investment. Also, the impact of rising fuel bills is placing pressure on all levy-funded low carbon measures and there is political debate over the role that RE should play in this context. But investment in solar PV is strong despite the prevailing conditions and it is showing signs of stabilising after the peaky investment profile that resulted from the cut-off dates for tariff reductions (BNEF, 2012).

The following section will bring together the analysis from this chapter and the last in order to evaluate how each system level (niche, regime and landscape) is interacting.

SECTION 8.4 THE INTERACTION BETWEEN THE NICHE, REGIME AND LANDSCAPE LEVELS OF THE ELECTRICITY SYSTEM

The analytical framework employed in this thesis has developed out of transition theory and specifically the MLP. The MLP is a contested theory of how change occurs within large socio-technical systems but it provides a useful framework for analysing a system by structuring it into three distinct levels; niche, regime and landscape. The *interaction* between those three levels is central to understanding the processes of change occurring within a system, and it provides the focus of this section. Firstly the analysis is synthesised in Table 8.1 to illustrate each process within the analytical framework and summarise the findings at each MLP level.

TABLE 8.1 SUMMARY OF ANALYSIS

Niche	**Learning Processes**	**Price-performance improvements**	**Support from powerful groups**	**Summary**
	A bulkhead of FIT activity has driven learning processes, particularly for solar PV. A period of stability is now required to consolidate these learning effects. Commercial innovation in the solar PV sector such as aggregated schemes have been adopted by established regime players (e.g. Big 6 and LAs). Financial innovation – project finance and new sources of early-stage investment have responded to the stable opportunity provided by the FIT. But the instability of the policy itself has damaged this innovation. Technological innovation and learning (e.g. SoLa BRISTOL, hydro fish passes) resulting from the installation increase and higher revenues driven by the FIT.	Capex of wind, hydro and AD has been static and is predicted to flat-line. Capex of solar PV has dropped rapidly. Solar PV reductions are the result of global trends but the FIT has brought the benefits to the UK. Non-module costs have also reduced as developers/installers scale-up and gain experience. Solar PV capex reduction has driven unexpected levels of installation which in turn has driven the other processes of transition within this framework.	Powerful groups have responded to the opportunity provided by the FIT, particularly for solar PV, but the handling of the scheme by DECC has threatened the continued presence of those groups in the sector. New investors have brought large amounts of capital into the solar PV sector; LAs and utilities have brought scale and expertise. This has increased the legitimacy of PV as a technology and asset class.	The FIT has driven a build-up of niche momentum in the solar PV sector. The impacts of this momentum will be limited by the processes occurring within the regime. The FIT has not yet driven a build-up of wind, hydro and AD niche momentum sufficient to move into the regime. Policy stability, and additional non-financial support is required for these niches.
Regime	**Changes in cognitive and regulative rules**	**Changes in technologies**	**Changes in social networks**	**Summary**

	A build-up of regulation aimed at creating a low-carbon electricity system is increasing the potential for developing alternative generation options. But regime actors are focused on capacity-adding technologies. The benefits of small-scale RE are not valued under this cognitive rule and the FIT has not significantly affected this at regime level. Further regulative change is required to drive small-scale RE development into the regime.	Solar PV capacity has grown very rapidly. If it continues to increase then the power markets and the distribution network may be affected, as has occurred in more mature markets. But large-scale technologies still predominate and are predicted to characterise the regime going forwards.	The 216,021 new generators created by the FIT are influencing the social networks of the regime but it is difficult to interpret how significant this is because the whole system is in a period of uncertainty. But successfully completed projects are increasing the legitimacy of small-scale RE amongst regime actors.	The FIT has affected the regime and some key regime-actors have responded to the scheme. The rapid rate of PV deployment has been a significant development in the system through demonstrating the application of alternative generation options. However a large-scale mind-set still largely prevails.
Landscape	**Macro-political developments**	**Socio-cultural practices**	**Macro-economic trends**	**Summary**
	The FIT is framed by a context of political instability concerning the electricity system. The response to climate change is highly politicised which has added risk to investment in, and development of, small-scale RE.	The most significant socio-cultural factor affecting the FIT is the unidirectional relationship between suppliers and 'consumers'. Energy-users are currently passive actors in the system which will be a challenge for future system development. Small-scale RE may stimulate a greater engagement with electricity but it is too early to tell the impact the FIT has had on this.	Recession of the UK economy has both negative and positive impacts on the FIT. Scrutiny of the scheme has increased as a spending cap was introduced as part of wider austerity measures, and energy bill-increases, and therefore levy-funder schemes, have become more politicised as household incomes have declined. But the stable return	The broad context surrounding the FIT is one of uncertainty. This offers both opportunities and barriers to small-scale RE development. The impact so far has been to increase the relative attractiveness of investment, particularly in PV, but to also create uncertainty (and risk) for the nascent sectors.

			offered by the FIT has become more attractive relative to low yield elsewhere and investment in PV has therefore been strong.	

The analysis above has explored how the FIT relates to three distinct processes within each system-level and evaluates whether they collectively indicate the potential for radical change. For example, if all three niche processes were combining to build momentum then the potential for the niche to break into the regime would exist. But the interaction between all three MLP levels is the indicator of what wider change is possible, or already occurring, for the whole socio-technical system (Geels and Schot, 2007). This section brings together the processes at each system-level and discusses the interaction between the niche, regime and landscape.

The FIT has had very different impacts on the four technology niches covered in this research. The dominance of solar PV under the scheme has meant that the focus of much of the analysis has been on developments within that niche. This following sections also focus on solar PV but Chapter 9 discusses the low deployment rates of the other three technologies and explains how policy could be designed to further integrate them into the electricity system.

SECTION 8.4.1 NICHE PROCESSES, LEGITIMACY AND INTERACTION WITH THE REGIME

The FIT has clearly been a very significant development for the solar PV niche, not least because sub 1MW PV investment grew by 1621% between 2010 and 2011 and the installation rate has consequently been dramatic (BNEF, 2012). As discussed in Chapter 7 the learning processes that have occurred within the sector are significant because they have resulted in a rapid increase in deployment but also because they have pump-primed the industry such that further deployment, at lower cost, is possible. In particular the financial and commercial innovation that has occurred to deliver aggregated solar PV schemes has introduced an economy of scale that was unforeseen at the introduction of the FIT. It has also encouraged powerful groups such as Local Authorities and Housing Associations into the PV niche which has created a momentum in the sector.

That momentum is significant for solar PV because a standard business model delivering domestic installations is inherently fragmented and irregular. Despite the short lead-time and sale-cycle for PV, deployment rates tend to fluctuate in response to external factors such as domestic financial cycles and crucially, tariff changes (Interview 1). But powerful groups such as Birmingham City Council with a program to install 10,000 domestic arrays can maintain a momentum in the sector such that installers, developers, scaffolding companies, and the supply chain are kept in business. This is a more sustainable position for the sector to be in and it increases the legitimacy of the technology-niche as a whole.

An increase in the legitimacy of any niche will encourage further support from powerful regime groups and the social networks that maintain stability in the regime may begin to open to new entrants from the niche. This interaction appears to be happening to a degree for solar PV. Big 6 energy utilities are responding to the solar PV market by contracting their own installation businesses but also working in partnership with other niche and regime groups. Figure 6.3 shows an aggregated solar scheme on 592 council houses in Aspley, Nottinghamshire. This scheme was a partnership between Nottingham City Council and E.ON, one of the Big 6 energy utilities. Partnerships such as this are potentially significant interactions between a niche-innovation and regime actors. The motivations for schemes such as this may be explained by the marketing or Corporate Social Responsibility opportunity that they provide, but the outcome could be significant in building capacity and legitimacy for the PV niche.

SECTION 8.4.2 REGIME NETWORKS AND POLICY RISK

A degree of financial innovation has also occurred within the solar PV niche, which has had a particular impact on the commercial projects such as large rooftop installations and aggregated schemes. These schemes have been the most innovative in finding opportunities to achieve scale. The financial innovation that has driven commercial projects has developed out of financing models used widely for investment in energy projects, and within other sectors. Project finance, SPVs, VCTs and EIS's are already well established but the FIT has provided a platform for adapting those models to solar PV projects. Again, this is significant in driving deployment but also for the interaction it involves between niche and regime. The meetings and events that were attended as part of the fieldwork for this research highlighted the rapidly developing networks that are emerging due to the FIT. Events such as Green in the City, Green Mondays, and The Carbon Show are all examples of big networking events that bring together niche and regime actors to discuss, principally, policy and finance of low-carbon technologies such as small-scale RE. The opportunities provided by the FIT are very much a part of these events.

There is certainly an increasing interaction between actors in the regime and the solar PV niche and it is reasonable to assume that this is influencing the social networks within the electricity system. But the regime is also influenced by the FIT policy itself, and the way in which it has been managed. DECC's handling of the cuts to solar tariff levels has been widely criticised and it has had a significant impact on the way in which actors outside of the solar-niche perceive the technology (EAC and ECCC, 2011). Events such as the Judicial Review into DECC's review process, and an investigation by the Energy and Climate Change Select Committee into DECC's tariff reductions, have created an uncertainty around the FIT but also about DECC's intentions for RE as a whole. If any of the FIT niches, or any RE niches, are going to advance into the regime they require the resources of regime actors. As discussed above, this is beginning to happen but it is fragile and it is dependent on a degree of trust between Government and industry. As the quote below from a Generation Strategy Manager at a Big 6 utility illustrates, this trust has been tested by the changes to the FIT.

> *'One of the biggest effects the FIT has had on me is probably related to policy risk. The fact that the Government will change the rules at such short notice, for albeit small scale, makes me worry about whether I want to invest in something at the large scale unless I have a guarantee up-front that I will get, actually get, the support on something which is supposed to be supported. So to me the biggest effect of the FIT so far is to undermine my confidence in Government' (Interview 22).*

This quote illustrates the way in which each MLP level can interact. The political uncertainty at a landscape level can affect the support provided for niche-technologies supported by the FIT, and the perception of risk held by actors in the regime. The only solution to this instability is political leadership and decisiveness in the face of landscape developments such as climate change. The example of solar PV deployment under the FIT illustrates how a new technology with alternative characteristics can achieve scale. Many of the technologies required for a low-carbon electricity system exist and the resources to deploy them are available but political resolve is required if the most appropriate technical, commercial and social configurations for that system are to be found. The unique political challenge posed by climate change is explored in the next section.

SECTION 8.4.3 LANDSCAPE DEVELOPMENTS AND THE RESPONSE OF THE REGIME

The degree to which a niche can interact with the regime is influenced by the processes that occur at a landscape level, and the way in which the regime responds to those processes. As Chapter 1 and Section 8.3 have discussed, the electricity landscape is changing. Climate change and energy security concerns are placing pressure on the existing regime to find alternative ways to generate and supply power. But these landscape developments are not what Geels and Schot term "*specific shocks*" or "*avalanche change*" (2007, p.409). They are long running issues that require a degree of foresight and political leadership. The impact that climate change is having on the electricity system in the UK is related to the political response; the direct physical impacts will mostly materialise later. The availability and access to energy resources is having an impact now, with rising wholesale gas prices as an example, but there is much further to go.

This lag in the impacts of landscape processes raises the politicisation of decision making because different choices can be taken at different times, and arguably have the same outcome (depending on the objectives). For example, if decarbonisation by 2030 was the sole objective of electricity policy, there are still many different pathways, combinations of technologies, and choices in timings that could achieve that. This politicisation of electricity policy often results in a lack of certainty because there are multiple options, multiple decisions, and multiple competing interests affecting outcomes. The quote at the end of Section 8.4.2 illustrates very clearly what can happen when uncertainty in decision-making occurs, and the ultimate result will be to slow the pace of change.

For solar PV under the FIT, it is not a lack of innovation or momentum within the niche that is preventing the technology becoming widespread in the electricity system, but it is the stability of the regime and the response of regime actors (e.g. DECC, Treasury, investors) to landscape developments. Electricity policy is currently highly politicised and uncertain because there is no political consensus over how to respond to climate change and energy security. This is limiting the potential for small-scale RE at the niche level to develop and to advance into the regime.

SECTION 8.5 CHAPTER SUMMARY

This thesis argued in Chapter 2 that the electricity regime is stabilised by the physical infrastructure, industry structure, institutional framework, market design and investment practices that have co-evolved around a large-scale configuration. There is an increasing body of regulation that is placing pressure on these elements of the regime to change and the FIT is only a small part of that. But the scheme has provided the support for an unprecedented influx of new generators and by that measure it has been a very significant development for the regime. Solar PV accounted for 20.2% of additional capacity between 2010 and 2011 (which includes a reduction of 83% to account for the load factor) (DECC, 2011d) and this thesis argues that this level of deployment is starting to change the cognitive rules/belief systems and social networks that characterise the regime.

The FIT is still a recent development and so the impacts it is having on the existing regime are still emergent. The cognitive and regulative rules, technologies, and social networks of the regime are inherently slow-moving because they are so dominant. This Chapter has shown that they are still mostly structured around large-scale technologies and it is unrealistic to expect the FIT to overturn this situation. But this thesis argues that the new technologies, actors and practices that the scheme has brought into the system have begun to disrupt the regime in the short period since it was introduced. But the response of the regime is influenced by a wider context developing at a landscape level, discussed below.

The structuring influence of the landscape on processes within a socio-technical system is a slow and complex interaction. This chapter has illustrated some of the key developments at the landscape level that have had an impact on the FIT. The macro-political context is unstable, caused in large part by the challenge posed by climate change. The political response in the UK has been at once ambitious *and* resistant. The decarbonisation targets may drive change in the future but the immediate context is highly politicised and uncertain. An impact of the FIT has been to create uncertainty which has delayed the development of projects, particularly non-PV technologies with longer lead-times.

The socio-cultural context is driven by wider patterns of consumption and in the case of electricity, it is characterised by passive energy *consumers* with little stake in the system. The FIT is aimed towards engaging these consumers but it is not yet clear whether that will be achieved. But that engagement relates to the debate over the costs of electricity to the end-user, and the role that low-carbon measures, such as the FIT, have in those costs. The retail market is also in a period of uncertainty and it is not clear what developments may occur, and what impact these will have on the FIT. But the macro-economic conditions that have created problems in other sectors appear to have been less disruptive for the clean energy sector and the solar PV sector in particular has seen rapid growth. What is now required is a period of stability so that the solar industry can settle and the other FIT niches can begin to develop further. But there is still much uncertainty in electricity policy and the FIT is exposed to any further volatility.

The chapter then drew the analysis together to evaluate the way in which each MLP level related to the FIT (niche, regime and landscape) is interacting and what this suggests about the role of the FIT in system transition. It concluded that the solar PV niche is developing rapidly and that it has built an internal momentum. The regime is responding to this development and employing resources into solar PV but the interaction between the two is threatened by wider political debates stemming from the landscape processes of climate change and energy security. These political debates are creating uncertainty for the whole electricity sector which is damaging the passage of change.

In summary, the interaction is characterised by the following factors –

1. The solar PV niche has built a degree of internal momentum under the FIT but further resources are required from the regime, including stable policy support.

2. The landscape is placing pressure on the existing regime through climate change and energy security developments but there is a lag in the impacts of these developments.
3. The regime is interacting with the solar PV niche and has already mobilised the resources to achieve rapid deployment. However, continued interaction with the niche level is dependent on wider political factors.
4. Those political factors relate to the way in which the regime is responding to the landscape developments. The lag of those developments has politicised electricity policy and confused decision-making. This has created uncertainty for both niche and regime actors concerned with the FIT which is hindering the passage of solar PV, and other small-scale RE, into the regime.

The next and final chapter brings the preceding chapters together, identifies and discusses the key themes emerging from the research and it draws conclusions on the role of the FIT in electricity system transition.

Chapter 9 – Summary, Emerging Themes and Conclusions

SECTION 9.1 INTRODUCTION

This chapter is split into seven main sections. Section 9.2 outlines the main points from each of the previous chapters in order to summarise the arguments that this thesis is making. Section 9.3 discusses three policy implications that have emerged from the research –

1. The 'pump-priming' effect that the FIT has had on the solar PV sector.
2. The importance of policy certainty/stability.
3. The value of diversity (in terms of scale, location and technology) in the electricity system and removing barriers to the development of wind, hydro and AD.

Section 9.4 discusses a key theme that emerged from the research; the role of the state in electricity transition. Section 9.5 explains the empirical, policy-evaluation, and theoretical contributions to knowledge that the thesis makes –

1. Empirical – An in-depth analysis of the first two years and five months of the FIT.
2. Policy evaluation – Demonstrating how policy can be evaluated in terms of its impacts on transition rather than costs or carbon saving.
3. Theoretical – A development of transition theory by operationising the MLP.

It also discusses the contribution that the thesis makes to the literature related to the GB FIT. Section 9.6 critically reflects on the analytical framework used in this thesis and discusses the contribution of the research to transition theory. Section 9.7 makes recommendations for further work and Section 9.8 concludes the thesis.

SECTION 9.2 THESIS SUMMARY

Chapter 1 outlined the broad energy and policy context that frames the FIT. It was explained that the UK now has a legal target to reduce carbon emissions by 80% by 2050 and a legal target to source 15% of total energy consumption from renewable sources by 2020. It argued that a transition is required in the electricity system if these targets are going to be met but many different combinations of technologies could drive that transition.

An underlying argument throughout this thesis is that small-scale RE technologies could make a significant contribution to system transition because they have a number of benefits including maximising the renewable resource; reducing network losses; enhancing system resilience by increasing the diversity of technologies; reducing the need for network upgrades by siting generation plant closer to demand; widening ownership of the electricity system and therefore increasing the acceptance of system-change; and raising awareness of energy use by reconnecting end-users with electricity generation (see Chapter 2 Section 2.3). Chapter 1 also showed that the technical potential (based on the available resource and the limitations of the technologies) of small-scale RE is 131.2 TWh/year. Although much of this could not be developed for economic and political reasons it still represents a significant resource in the UK and the thesis therefore focuses on these technologies and the policy designed to support them.

Chapter 2 explained that the physical infrastructure of the UK electricity system is dominated by large-scale thermal and nuclear generating plant and the industry structure, institutional framework, market design and conventional financing practices of the system have all developed around the large-scale infrastructure. It is argued here that these elements ultimately maintain the large-scale configuration and lock out small-scale alternatives. Targeted policy support is therefore required to overcome lock-in and compensate for the disincentive to develop small-scale projects. The FIT has been introduced to provide this support and this research therefore focuses on the impacts that the scheme has had.

Chapter 3 explained the theory of transition in socio-technical systems such as the electricity system. It presented the MLP which breaks a system down into the niche, regime and landscape levels. The MLP is chosen as a theoretical lens in this thesis because it provides a useful structure with which to analyse the many interrelated processes, developments and dynamics occurring within the electricity system around the FIT. The chapter explained that the analytical framework is based on the structure of the MLP and a number of processes identified in the literature to be indicators or requirements of transition. These processes structure the analysis and consequently *operationalise* the theory of the MLP.

Chapter 4 explained the three empirical sources that have been used in this research –

1. 37 semi-structured interviews;
2. Attendance at industry and Government meetings;
3. Secondary analysis of consultation responses, publications and statistics from Government and Ofgem.

It also stated how the data from these sources was analysed and how the analytical framework was applied.

Chapter 5 explained that the NFFO and the RO were designed to deliver low-cost RE capacity and the majority of the technologies that are supported under these schemes are large scale, mature technologies owned by a small number of companies. Also, because the RO is a complex mechanism it is difficult for small-scale and independent actors to engage with and therefore the amount of small-scale RE capacity it has delivered is low. This thesis argues that the deployment of small-scale RE could deliver a number of benefits including the introduction of new market entrants which could mobilise new pools of investment, increase the number of beneficiaries in the electricity system, and improve buy-in to system transition and acceptance of change. It is suggested that small-scale technologies therefore require specific policy support that has not been provided by the NFFO or the RO.

The chapter argued that the microgeneration grant schemes that existed before the FIT were inconsistent and did not provide the support required to develop a sector. But FIT mechanisms have been introduced in many countries because they remove some of the key risks for small-scale generators in providing a guaranteed price and buyer for power. In doing this FITs have been argued to insulate small-scale projects from the electricity market and provide a secure and certain platform for investment. The thesis then evaluated how successful the GB FIT has been at insulating solar PV, wind, hydro and AD generators and it explored how this has impacted on the process of transition in the electricity system.

Chapter 6 argued that the rate of deployment under the FIT is unprecedented in the UK with neither the NFFO, RO nor the previously available microgeneration grant schemes, driving installation rates that are close to that driven by the new scheme. The chapter explained that solar PV has been the dominant technology under the FIT and the vast majority of installations are sub 4kW domestic arrays. The number of solar PV installations has been driven by a number of factors including the introduction of aggregated solar schemes, a higher than expected amount of commercial PV capacity, an underestimation of investor hurdle rates in the initial modelling done for the FIT, and low interest rates elsewhere in the economy incentivising the returns available from FIT-supported PV. But the principal factor is the 49-66% reduction in capex for a PV installation since the FIT was introduced. DECC were not able to respond to this unexpected level of cost reduction with a parallel reduction in tariff rates, and deployment has consequently been very high (DECC, 2011g).

The chapter explained why hydro, wind and AD deployment has been so low in comparison to solar PV. This thesis argues that these technologies have a number of additional barriers to development that PV does not have, such as planning and licensing consents. It suggests that these need to be addressed directly if the non-PV technologies are going to be more widely deployed (discussed further in Section 9.3). It also argues that the example of solar PV shows that small-scale RE capacity can be delivered quickly if given the right support.

Chapter 7 applied the analytical framework at the niche level. It showed that the FIT has been a very significant policy mechanism for the small-scale RE sector. In particular, the solar PV niche has developed hugely since the scheme was introduced which has resulted in a high deployment rate but also there is evidence of learning processes, price-performance improvements and support from powerful groups and the thesis therefore argues that momentum is building for this technology-niche.

The costs of solar PV have fallen dramatically since 2010, driven largely by a global reduction in module prices but also affected by the commercial and supply-chain development that the GB FIT has stimulated. It is difficult to quantify the weighting of each factor in the reduction of PV installation costs but the non-module factors, that are more directly driven by the FIT, are likely to have a significant role going forwards as the module price begins to stabilise as predicted (PB, 2012a). The price-performance improvements that are a requirement for building niche momentum have clearly occurred for solar PV.

There is also evidence of powerful actors such as investors, Local Authorities and energy utilities moving into the solar PV space. This is building momentum in the PV niche and accessing regime resources, investment and expertise.

The chapter explained that the FIT has provided a platform for commercial and financial innovation and has brought some technological innovation to the UK. This has had a significant role in driving solar PV deployment and in developing the sector. The changes to the FIT have impacted on this innovation in the short-term, mainly by increasing the risk associated with the scheme but the thesis argues that the learning processes that have been demonstrated have created a foundation for further development in the long-term. It is argued that these processes were not occurring before the FIT was introduced and the scheme is therefore a driver of niche momentum; a process that is central to transition.

The wind, hydro and AD niches have not seen the same degree of learning, price reduction, or powerful support due largely to the low deployment rates for these technologies. Section 9.3 explores why this has occurred in more detail.

Chapter 8 applied the analytical framework to the regime and landscape levels. It explained that there is an increasing body of regulation placing pressure on the regime to change and the FIT is only a small part of that. But the scheme has provided the support for an unprecedented influx of new generators and by that measure it has been a very significant development for the regime. Also, solar PV accounted for 20.2% of additional capacity between 2010 and 2011 (which includes a reduction of 83% to account for the load factor) (DECC, 2011d) and this thesis argues that this level of deployment is *beginning* to change the cognitive rules/belief systems and social networks that characterise the regime.

The FIT is still a recent development and so the impacts it is having on the existing regime are still emergent. The cognitive and regulative rules, technologies, and social networks that exist are inherently slow-moving because they are so dominant. The chapter argued that they are still mostly structured around large-scale technologies and it is unrealistic to expect the FIT alone to overturn this situation. But it is argued that the new technologies, actors and practices that the scheme has brought into the system are a positive step for transition and increased deployment, including the non-PV technologies, is required to disrupt the regime further.

The structuring influence of the landscape on processes within a socio-technical system is a slow and complex interaction. The chapter illustrated some of the key developments at the landscape level that have had an impact on the FIT. The macro-political context is unstable, caused in large part by the unique, long-running challenge posed by climate change. The political response to this challenge in the UK has been at once ambitious *and* resistant. The decarbonisation targets are bold and they are likely to drive change in the future but the immediate political context is highly politicised and uncertain. The impact on the FIT has resulted from uncertainty over Government's intention and this has delayed the development of projects, particularly non-PV technologies with longer lead-times.

The socio-cultural context is driven by wider patterns of consumption and in the case of electricity, it is characterised by passive energy *consumers* with little stake in the system. The FIT is aimed towards engaging these consumers but it is not yet clear whether that will be achieved or what the impact will be. But that engagement relates to the debate over the costs of electricity to the end-user, and the role that low-carbon measures, such as the FIT, have in those costs. The retail market is also in a period of uncertainty and it is not clear what developments may occur, and what impact these will have on the FIT. But the macro-economic conditions that have created problems in other sectors appear to have been less disruptive for the clean energy sector and the solar PV sector in particular has seen rapid growth. What is now required is a period of stability so that the solar industry can settle and the other FIT niches can begin to develop further. But there is still much uncertainty in electricity policy and the FIT is exposed to any further volatility.

The chapter then drew the analysis together to evaluate the way in which each FIT-related MLP level (niche, regime and landscape) is interacting and what this suggests about the role of the FIT in system transition. The interaction was broken down into four relationships -

1. The solar PV niche has built a degree of internal momentum under the FIT but further resources are required from the regime, including stable policy support.
2. The landscape is placing pressure on the existing regime through climate change and energy security developments but there is a lag in the impacts of these developments.

3. The regime is interacting with the solar PV niche and has already mobilised the resources to achieve rapid deployment. But continued interaction with the niche level is dependent on wider political factors.
4. Those political factors relate to the way in which the regime is responding to the landscape developments. The lag of those developments has politicised electricity policy and confused decision-making. This has created uncertainty for both niche and regime actors concerned with the FIT which is hindering the passage of solar PV, and other small-scale RE, into the regime.

SECTION 9.3 POLICY IMPLICATIONS EMERGING FROM THE RESEARCH

This section discusses the policy implications that have emerged from the research. The themes are listed below.

1. The 'pump-priming' effect that the FIT has had on the solar PV sector (Section 9.3.1).
2. The importance of policy stability and certainty (Section 9.3.2).
3. The value of diversity (in terms of scale, location and technology) in the electricity system and removing barriers to the development of wind, hydro and AD (Section 9.3.3)

SECTION 9.3.1 PUMP-PRIMING THE SOLAR PV SECTOR

This thesis has argued that small-scale RE technologies could bring a number of benefits to the UK electricity system and they could have a significant role in driving the transition to a decarbonised and sustainable system. However, despite twenty years of renewables policy in the UK, small-scale RE was not widely deployed before the FIT was introduced in 2010. Neither the NFFO, RO, Major Photovoltaic Demonstration Programme, Clear Skies nor the Low Carbon Building Programme had driven a scale of deployment that would allow the small-scale RE niches to develop through experience or significantly reduce costs. The FIT has driven that scale of deployment for solar PV and the rate of installation has been unprecedented in the UK.

The analysis in Chapter 7 argued that a bulkhead of activity was required within the solar PV niche in order to overcome the details of installation such as how to install in different locations, how to productise the technology so it can be widely sold, or how to find the contractors required for installation (e.g. scaffolding companies). These details require experience that can only come with cumulative deployment of a technology but once they are overcome or standardised the installation costs should reduce. If a technology is established then it may start to display 'increasing returns to adoption' (introduced in Chapter 1) (Arthur, 1994). This thesis argues that the FIT has provided the 'pump-priming' platform that has allowed solar PV to become established and to begin to display increasing returns to adoption. It still requires policy support now but if the installation costs continue to reduce then PV may become competitive with the retail price of electricity and the FIT should no longer be required to drive deployment.

If the FIT is assessed in terms of its success in delivering capacity then it has been expensive and inefficient. If it is assessed as a commercialisation policy or in terms of its role in pump-priming the solar PV niche and delivering a scale of deployment that would spur increasing returns to adoption then the scheme has been successful for solar PV. The quote below from The Carbon Plan, a central UK Government document outlining climate and energy policy, suggests that this pump-priming is a goal of Government policy in the short-term -

'In the 2020s, we will run a technology race, with the least-cost technologies winning the largest market share. Before then, our aim is to help a range of technologies bring down their costs so they are ready to compete when the starting gun is fired' (HMG, 2011, p.3).

This thesis argues that driving an initial boost of solar PV capacity is an important step in the transition of the electricity system because it opens some of the benefits of small-scale RE. Despite the criticism, multiple reviews, and costs that the FIT has created since it's introduction, the lasting impact of the first two years and five months is to have stimulated the deployment of a technology that could have a significant role in the future system and could present part of an alternative to the dominant large-scale configuration.

This section has explained that the FIT has been a significant driver for solar PV which is beginning to impact on the wider electricity system. The impacts are buffeted by wider political factors that create uncertainty in the small-scale sector and, as the next section explains, this impacts on the ultimate costs of delivering a scheme.

SECTION 9.3.2 'VOLATILITY IS THE ENEMY OF INNOVATION'

Every stakeholder interviewed for this research discussed the reviews of the FIT and the importance of policy stability for the development of the FIT-niches. This was also the central topic of discussion at many of the conferences and meetings attended during the fieldwork. It has been a dominant issue for the stakeholders in the FIT niches, and for solar PV in particular. An uncertainty was created by the way in which DECC responded to the sharp reduction in solar PV module prices, which in turn is linked to the broader debate across UK Government over the role of RE, small-scale RE and the policies designed to support them (see Chapter 8 Section 8.3.1).

The analysis has shown that the FIT has successfully driven the niche processes identified in the analytical framework for solar PV. A build-up in niche momentum is evident and the regime is responding by providing resources and expertise which is driving deployment. But this thesis argues that the political debate surrounding the role of RE is damaging the potential for innovation and development of the FIT niches. The quote below is repeated (from Chapter 8) because it clearly illustrates the impact of policy uncertainty.

> *'Financiers and developers will always be better at innovating if you've got a stable platform, and you can actually build something on that stability. If you've got a rocking platform you've just got people dancing around and you can't really build very much on top of it. That volatility is the enemy of innovation'* (Interview 16).

The impact of policy uncertainty is not limited to the technology affected by a change in the FIT (i.e. solar PV). As discussed in Chapter 7 Section 7.5, the changes to the scheme have had an impact across the whole electricity sector by increasing the perceived risk of policy change which increases the cost of capital for all power projects, and ultimately drives up the costs of electricity. In relation to the FIT, it is argued here that the impact can be greatest on technologies with a longer lead-time such as wind, hydro and AD. There is a perceived risk that the FIT will be reduced or removed whilst the project is being developed which adds uncertainty to the return that will be made once the project is generating. One interviewee suggested that DECC’s attempts to limit solar PV investment had created an environment in which investment in anything other than PV was too expensive due to the perceived risk of policy change (Interview 9).

The FIT has been successful at insulating projects from the rest of the electricity market and the protection it provides overcomes the large-scale bias in the system created by the physical infrastructure, the industry structure, the institutional framework, the trading arrangements and the investment practices (see Chapter 2). However, this is threatened by the political instability currently surrounding the FIT and RE support in general. This thesis argues that the UK Government’s response to landscape processes such as climate change and the recession of the UK economy has increased the costs of small-scale RE development and slowed the rate of deployment. It is suggested that a clearer signal of political intent could create a more stable commercial environment and reduce the costs of delivering projects.

The analysis in this thesis has mostly focused on solar PV because it has been the dominant technology supported under the FIT. It is argued here that the other FIT technologies have additional benefits that could contribute to transition, discussed in the next section.

SECTION 9.3.3 THE VALUE OF DIVERSITY IN TECHNOLOGIES AND SCALES

The dominance of domestic solar PV under the FIT is explained by a number of factors. It is a simple technology to install, it typically has a short sale-cycle, it is a permitted development, there is low technical risk, and the initial tariff was very generous. There is a large, accessible resource on south facing roofs in the UK and it therefore has a very wide potential application. However, sub 5MW wind, hydro and AD could provide additional benefits to the system and maximise the available renewable resource. This thesis argues that there is an inherent value to increasing the diversity of small-scale generation options. With diversity comes new sites, new sources of investment, an increased resource/weather base, more connection points to the network, and less concentrated supply-chains (see Chapter 2 Section 2.3). These factors could increase the resilience of a system by lessening the impact of a shock to one location, technology or resource.

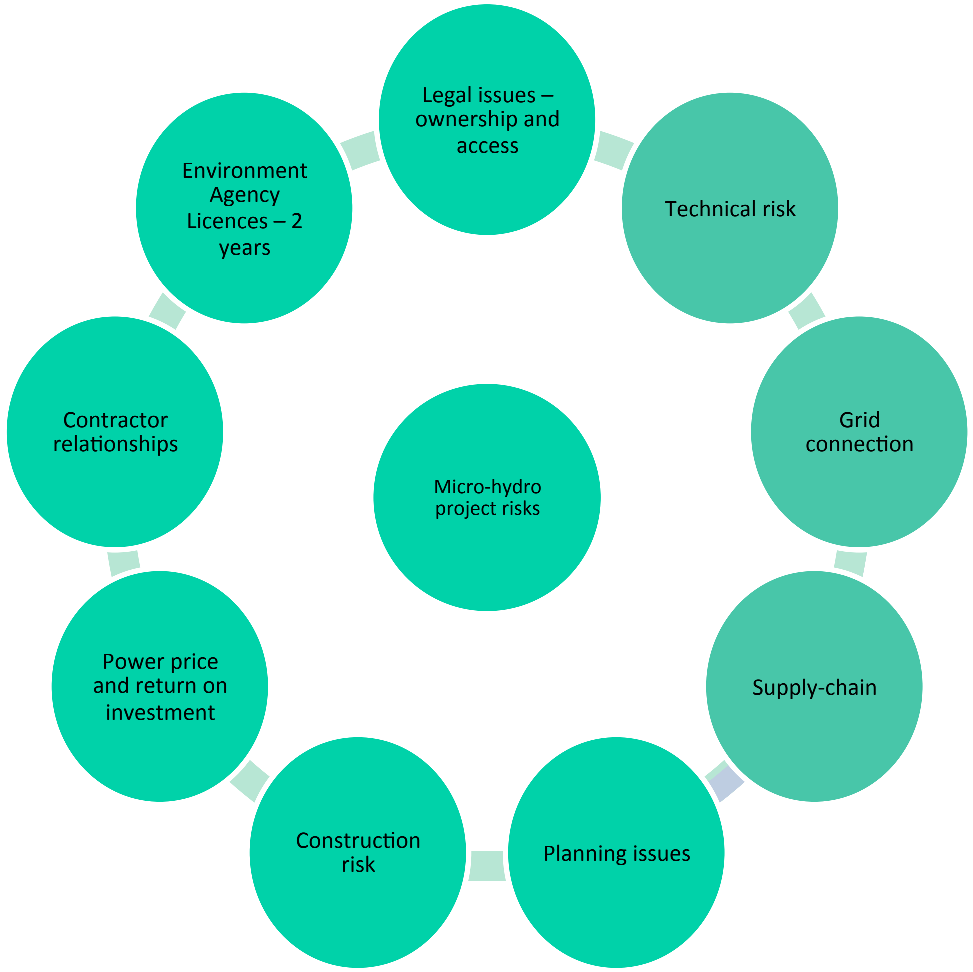
The quote below from a DECC interviewee illustrates why diversity is important in current UK electricity policy -

*'The starting point (*for the FIT*) came from the* (EU*) renewables directive because you need many different kinds of investors doing as many different kinds of things in parallel so you get as much renewable energy development as possible and manage to meet that target. The starting objective (*of the FIT*) was that it needs to fulfil a role in widening the portfolio of options on the table. And it does that in two ways. Firstly by widening the kind of technologies you're employing. Secondly by widening the types of investors you hope to attract. Not just the Big 6, as under the RO, but also anyone else basically. And that's where the simplicity of the FIT comes in' (*Interview 13).

The FIT has delivered for domestic solar PV and there has been some innovative investment in this area. However, the scheme has not stimulated the *diversity* of technologies and investment proposed above. It is argued here that an increased deployment rate for wind, hydro and AD would mobilise further innovation and investment in the electricity system and add to the impact driven by solar PV.

Both wind and AD have delivered less than the modelled figures and the predicted hydro figures were set low despite a large resource. The tariff levels do provide a reasonable return for these technologies, with an estimated 3 – 8 year payback for wind projects as an example (RenewableUK, 2012), but as indicated throughout the thesis, each technology faces a number of project risks, that domestic PV does not have, that are preventing developers from deploying at scale. This thesis argues that addressing these risks directly through policy or coordination (explained in Section 9.5.4) could begin to facilitate a more balanced deployment of small-scale RE technologies that would consequently achieve the diversity benefits discussed above. Some of these project risks for hydro development are in Figure 9.1.

FIGURE 9.1 PROJECT RISKS FOR MICRO-HYDRO DEVELOPMENT



Some project risks are inherent to the technology and cannot be addressed through policy (e.g technical risk). Also, many of these project risks are non-financial and cannot be removed through adjusting the tariff levels of the FIT. However, it may be possible to address some of the risks through directed policy or coordination. For example, planning risk is a very significant barrier to achieving scale for all of the non-PV technologies. Due to the high-risk associated with gaining planning consent development finance (a distinct form of investment that precedes project financing and gets projects through the consenting stage) is extremely expensive. This can add significantly to the overall costs of delivering a renewable project (Interview 14, 16, 20 & 28). This thesis argues that there could be a role for policy, outside of the FIT, in constructively and sensitively facilitating a more streamlined approach to planning applications through, for example, community engagement or planning committee education (see Chapter 7 Section 7.3.2). If policy can address issues such as planning then the overall costs of delivering small-scale RE will reduce and a higher deployment rate would be possible.

An example of where project barriers have been directly addressed is related to community RE projects (Interview 26 & 30). The FIT has removed a risk for community groups because it secures the returns that a project will make through guaranteeing a generation tariff. Two additional barriers for community RE schemes are that groups face problems in funding early stage resource assessment, scoping and feasibility studies, and there are also big difficulties in raising development finance to get projects consented. However, in December 2011 a Local Energy Assessment Fund was announced by DECC which provided small grants (~£50,000) to community groups to assess the potential for energy efficiency and local RE generation options. In November of 2011 a Rural Community Renewable Energy Fund was announced by DEFRA[48] which will provide loans from a revolving fund[49] for development finance (DEFRA, 2012). Thus in combination the FIT, the assessment fund and the RE Fund address some of the significant barriers faced by community groups in getting RE projects developed and there is therefore a cautious optimism about what progress could be made once the Rural Community Renewable Energy Fund is launched (Interview 26 & 30).

This thesis argues that this sort of deliberate intervention into the barriers of RE development could facilitate a higher deployment rate if applied to specific small-scale RE technology classes. For solar PV, making a return on the initial investment was the most significant barrier to development and the FIT provided for this. However, as Figure 9.1 illustrates, the return on investment is just one consideration in the development of hydro projects. Wind and AD development have similar additional barriers. If the goal of policy is to stimulate deployment, and reduce costs, then it would make sense to assess all the factors involved in development and then address the ones that could hold projects up and increase their costs. In other words, policy, in addition to the FIT, should work up from the development and investment requirements of each technology.

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[48] DEFRA is the Department of Environment, Food and Rural Affairs.

[49] A revolving fund is established to provide loans that, once repaid, are lent out again to similar projects or businesses. It is expected that the Rural Community Renewable Energy Fund will be repaid by the income from the RE schemes (DEFRA, 2012).

The means by which policy may be more targeted to the needs of each technology is an area for further work. One potential option is for a third party to coordinate renewable development within an area. This is discussed in more detail in Section 9.6.4. The following section discusses a theme that was consistently raised in many of the discussions, interviews and analyses carried out in this research; the role of Government within the process of transition.

SECTION 9.4 DISCUSSION POINT - THE ROLE OF THE STATE IN ELECTRICITY SYSTEM TRANSITION

A recurring theme that emerged from the fieldwork and analysis phases of this research relates to the role of the state versus the market in making a transition to a sustainable electricity system. Since the Electricity Act 1989 electricity policy in the UK has largely been guided by economic theory and a principle of private companies delivering competitive generation and supply through lightly regulated markets (Mitchell, 2008). Even support mechanisms that have been introduced in addition to the power market have been designed to be competitive market-based instruments (e.g. the RO). The role of the state has been intentionally minimised (Moran, 2004).

However, recent Government literature indicates the need for a transition in the UK electricity system, and work around the EMR suggests that Government are acknowledging that markets will not be able to meet all the challenges that a transition entails (DECC, 2011a; DECC 2011b). However, intervention into the electricity market is not straightforward and it can take many forms from wholly deregulated to nationalised industries. Where to place policy design between these two poles is the challenge currently facing Government and it appears as if there is a tension, or at least a lack of clarity, over where the balance should be. The acceptance of a need for intervention is countered by an enduring belief in the capacity for markets to deliver the most efficient solution and two decades of economic theory underlying electricity policy-making.

Several regime level actors who were interviewed in this study discussed how the role of DECC, Treasury, Ofgem, and the market is changing, and indicated that this change was sometimes a struggle -

'*I think DECC has been dominated, as has BIS (*the Department for Business, Innovation and Skills*) and Treasury, by people that think markets work in spite of all the evidence, particularly in the energy retail market which the regulator is saying is not very competitive and that they (*the suppliers*) all follow similar pricing strategies. But the struggle you're witnessing is the internal ideological struggle within individuals who believe one thing and have to do another. So like with the FIT, it's very structured but "let's just leave that bit out so it will make it feel like more of a market mechanism even though that actually creates a lot of risk in the process". I think that is still quite a dominant process*' (Interview 26).

As this quote suggests, the lack of clarity over how the state should intervene in the electricity sector can create risk for stakeholders because instruments end up being a compromise between contradicting objectives. The interviewee is arguing that personnel within Government and regulatory institutions are having to introduce interventionist policy against their beliefs of how the electricity system should be governed. This view is supported by the rhetoric emerging from DECC which broadly suggests that climate change represents a market failure that requires Government intervention but that this is a short-term fix which will be removed and competition will be allowed to continue in the future. For example, the 2011 Carbon Plan argued –

'In the 2020s, we will run a technology race, with the least-cost technologies winning the largest market share. Before then, our aim is to help a range of technologies bring down their costs so they are ready to compete when the starting gun is fired' (HMG, 2011, p.3).

More recently Ed Davey, the current Secretary of State at DECC, suggested –

'The reforms in the Energy Bill are specifically designed to move us away from such intervention – and blaze a trail towards competition. That is their ultimate aim' (Davey, 2012).

The roots of this temporary interventionist policy came from the previous New Labour Government before they lost power in 2010. Kuzemko (2013) discusses how energy security and climate change concerns came together to build pressure on the Government and Ofgem in 2007/2008. During this period a number of reports and critiques emerged which challenged the potential for market-based policies to meet the UK's RE targets, energy security objectives and carbon reduction targets as laid out in the new Climate Change Act 2008 (see Chapter 1 Section 1.3). These reports included the Energy Supply Probe by Ofgem (Ofgem, 2008b), the CCC's Fourth Carbon Budget (particularly Section 5 of Chapter 6 which was critical of the ability of the existing trading arrangements and policy framework to deliver electricity decarbonisation)(CCC, 2008a) and also the Stern Report which argued that climate change represented '*market failure on the greatest scale the world has ever seen*' (Stern, 2006, p. 27). As market failure provides justification for state intervention within economic theory this high level critique laid the ground for a different form of policy-making, and as Kuzemko discusses, the formation of an emerging security-climate paradigm for energy which includes an increased level of state involvement, if only temporarily.

In 2010 the New Labour government was replaced by a Conservative-Liberal Democrat Coalition government led by the Conservative party who were traditionally aligned with the model of deregulation and competitive markets. However, the limited intervention approach to electricity that had been developed under the previous Labour Government was largely maintained despite strong factions within the Conservatives disagreeing with this. An example was demonstrated by the very public argument in 2012 between the Chancellor of the Exchequer George Osborne and various personnel at DECC over the level of support to be provided to onshore wind in the RO Banding Review (Osborne, 2012; DECC, 2012). This argument raised the issue of whether support should be provided for low-carbon technologies at all and the degree of intervention that is acceptable to Government and society. The support level was left alone eventually but it was the Liberal Democrats, who represent the minor party in coalition, who were credited with delivering this continuing policy support (e.g. Blackburne, 2012). The Liberal Democrats may also be largely responsible for the continuation of this interventionist form of governance, particularly given that the two Secretaries of State at DECC have both been Liberal Democrats. But also, as described above, the case had been made on the need to change the approach to electricity policy and the CCC and DECC were already staffed with people working towards this end.

The FIT is a very interesting development within this wider shift in the thinking around electricity policy because it represents a clear intervention into the market and it was introduced one month before the general election and a change of Government. The mechanism pulls sub 5MW low-carbon generation out of the electricity market, creates a separate classification with separate regulatory rules (e.g. guaranteed offtake), and administratively sets the prices that generators receive for their power. It followed successful mechanisms introduced in Europe, most notably in Germany and it was in part an acceptance that market-based mechanisms such as the RO were insufficient to deliver the UK's renewables targets. In the Comprehensive Spending Review that was undertaken by the new Coalition Government many stakeholders in the RE sector were preparing for a dramatic cut to the FIT or a removal of the mechanism altogether (Interview 7). The fact that it remained in place, although with a newly introduced budget, indicated that the new Government had also accepted the need for interventionist policy.

The FIT was initially designed to be a simple mechanism that could be understood by non-energy professionals. But in ensuring simplicity, DECC failed to build in the flexibility to respond to deployment levels, technology capex reductions or a cap on allowable levy-funded spending. They therefore had to review the scheme several times and it now looks considerably different to the initial design and is far more complex and directed (e.g. contingent regression [see Chapter 5 Section 5.8.5])(EAC and ECCC, 2011). Thus, an intervention into the electricity market has required closer and closer supervision such that the scheme is now very tightly controlled and the high level of intervention is quite removed from the principles of deregulated, liberalised markets that underpinned privatisation.

The mechanisms to be introduced under the 2012 Energy Bill (CfD, Capacity, Mechanism, Energy Performance Standards and the already introduced Carbon Price Floor) also mark a considerable intervention into the market that are likely to require significant administration by Government and Ofgem. It remains to be seen whether, as the quotes above from Ed Davey and the Carbon Plan suggest, this intervention is only temporary and efficiently functioning competitive markets will return, or whether a new interventionist paradigm is forming that will not be easily removed. The removal of support for different technologies rely on the right technologies being supported now such that they can complete in the future but this thesis argues that the complexity of addressing climate targets will throw up unforeseen challenges that require a continued, important role for state-level intervention.

The next section outlines the three main contributions that this thesis makes.

SECTION 9.5 CONTRIBUTIONS OF THIS THESIS

This thesis has made three distinct contributions to knowledge; empirical, policy evaluation, and theoretical. This section outlines those contributions and discusses the way in which the research has enhanced the previous published research related to the GB FIT by Cherrington et al. (2013) and Walker (2012).

Empirical Contribution: This thesis makes a clear empirical contribution by presenting an in-depth, detailed analysis of the first two years and five months of the FIT. The FIT is still an emergent development in the UK electricity system and it is therefore too early to draw conclusions from the installation and cost figures alone. The system in which the scheme exists is based around a physical infrastructure but there are also social, economic, institutional, and commercial aspects that shape the impacts of a policy mechanism. This thesis provides a narrative account of the FIT as it relates to these system aspects. The account is informed by qualitative empirical research that contextualises the scheme and discusses how stakeholders in the system are experiencing it.

The FIT has been a significant development in the electricity system and it has had impacts beyond the FIT-related small-scale RE sector. Consequently there is a broad interest in the scheme and this research has relevance to academic, industry and policy circles focused on electricity policy, the decarbonisation of energy systems and concerned with the FIT. In addition, the research analyses Government policy and the findings and conclusions could be used to inform future policy-making. The thesis therefore has relevance for policy makers.

Policy Evaluation Contribution: Conventional energy policy analysis focuses on quantitative impacts and reports on the costs or carbon-saving of a policy. This research makes a unique contribution by presenting an analysis of a policy mechanism in terms of its impacts on a *dynamic system*. The analysis recognises that the electricity system is changing and evaluates what role the FIT is having within that wider process. It argues that if a policy is designed to contribute to transition then it should be evaluated in terms of its impacts on change. Transition theory is employed as a lens onto the process and is applied to the empirical findings using the structure of the analytical framework.

Transitions are complex processes involving social, technical, economic and institutional factors. A contribution of this thesis is to illustrate a method for analysing policy within this context.

Theoretical Contribution: Transition theory is in constant development. Research in this field has developed around historical analyses, Transition Management, and socio-technical scenarios. There is less research that applies the theory to existing policy. The theoretical contribution of this thesis is to develop transition theory by demonstrating how the theory can be applied to policy evaluation as the policy progresses. This builds on Kern's research (2012) to operationalise the theory and it therefore contributes to knowledge of how transitions occur in reality.

Contribution to existing FIT-related literature: Section 1.7 in Chapter 1 reviewed the two articles relating to the GB-FIT that have been published at the time of writing. It showed that Cherrington et al. (2013) presented a useful financial analysis of the economics of a typical sub 4kW system under three different tariff rates and that Walker (2012) attempted to model the contribution that FIT supported technologies would make to electricity supply in 2020. This thesis has made a quite distinct contribution to these articles by evaluating the FIT in terms of its role in the dynamic process of transition. It has employed transition theory to analyse the broader impacts of the FIT and contributed a qualitative knowledge of the scheme through seeking the perspectives of stakeholders in the electricity sector. The thesis therefore has a different focus to the two published articles and does not directly challenge or continue their findings. However, the broad conclusion of Cherrington et al. (2013) that the economics of solar PV still support a continued development align with the findings of this research, although this may be challenged by the on-going regime-level response to landscape developments such as climate change.

This thesis extends the existing academic research related to the FIT by broadening the focus beyond deployment levels and financial analysis to include qualitative impacts of the scheme and the role of the FIT in a wider process of transition.

The next section reflects on the utility of the analytical framework employed and the contribution to transition theory.

SECTION 9.6 METHODOLOGICAL AND THEORETICAL REFLECTIONS

This section critically reflects on the analytical framework that was used in this thesis and then discusses the contribution the research makes to socio-technical system transition.

SECTION 9.6.1 METHODOLOGICAL REFLECTIONS - ADAPTING KERN'S FRAMEWORK

There is a danger in applying an analytical framework to a policy mechanism with it's own objectives that the analysis will be assessing against criteria that did not drive the policy design. It would not be constructive to blindly evaluate the role that a policy mechanism has in transition, using a framework of indicators of transition, if the mechanism was not designed to achieve that end. A difficulty with the FIT, methodologically and generally, is that many objectives have been associated with it since it was first discussed. Different actors are therefore evaluating the success of the scheme against different criteria and their analyses will consequently reach different conclusions.

The FIT is one of a suite of policies that are working towards a transition in the UK electricity system but that is not its sole objective (see Chapter 5 Section 5.8.7). It was therefore not appropriate to apply a rigid analysis but to be flexible in applying the framework in order to pull out the important processes and trends occurring under the FIT. This was presented in Chapters 5, 6 and 9 where the discussion provided context and greater depth to the analysis. It is a necessary process in the application of the framework presented here to provide this additional analysis; an uncritical application of the framework may result in an analysis that misses key aspects of the policy.

One of the central reasons for selecting the analytical framework was that it would go beyond a cost-benefit, or carbon saving, analysis and identify the role of the FIT within a *dynamic* process of transition. This was not a straightforward task because the FIT is still in existence and developing daily. Over the course of the research period much has changed in the electricity policy world and it is not clear within the framework how this was to be analysed. The order of events surrounding the FIT, and the wider electricity system, and their interrelation is critical in understanding how change is occurring but the analytical framework is structured around the processes occurring at different levels (niche, regime and landscape). As Smith et al. (2010) argue, research into existing systems will always be '*partial, situated and temporary*', without the benefit of retrospect afforded by historical analyses (p. 445). This issue was addressed in this thesis by providing a reflexive narrative account of the FIT as it relates to the dynamic system but it was necessary to temporally boundarise the study to a degree. It may be important in analyses such as these to identify what happened at particular points and to explore what else was occurring in the system at that time. It is not merely enough to analyse what is occurring on one date. This is possible within the framework but it requires sensitivity on the part of the researcher and needs to be a clear element of any future analyses.

It is important to note when applying the framework that it does not just present a tick list of processes. It is also critical to evaluate the way in which the processes relate to each other and the way in which each level of the MLP is interacting. This was discussed in Chapter 8 of this thesis but it is not a large part of Kern's paper (2012). Despite presenting a coherent analysis, Kern does not focus on the interactions of processes and MLP levels and it is argued here that this should be a central element of future analyses.

A key strength of the framework is in providing a structure for analysis. Any socio-technical system contains "multiple equilibria" that are difficult to bring under analytical control (Schumpeter, 1954 in Arthur, 1984). It is a significant advance provided by the MLP, that complex systems can be broken down into analysable elements. The way in which a system is broken down will always be contested because different actors, and different researchers, experience and view the system in differing ways. But the lens provided by the MLP, and the development of this perspective into an analytical framework, allows researchers to structure empirical information. The interpretation of this information still requires considerable sensitivity on the part of the researcher and further work could be undertaken with other policy mechanisms to demonstrate how the broken down information can be analysed.

SECTION 9.6.2 THEORETICAL REFLECTIONS – SOCIO-TECHNICAL SYSTEM TRANSITION AND THE MLP

As discussed in Section 9.5, the theoretical contribution of this thesis is to operationalise a theory that has received much academic attention in recent years. Much of the academic work has been in developing the theory of transition and applying it to historical case studies. Kern's contribution was to draw processes out of the literature that are necessary for a transition to occur and then to identify whether they were occurring in response to the Carbon Trust. This thesis has built on this work by applying the framework to a different policy mechanism, and thereby further testing the utility of the framework for evaluating policy as it develops.

This is an important contribution to the transition literature because it is helping to build a bridge between theoretical academic development and real-life policy evaluation. The purpose of research into system transitions to sustainability is to identify how change occurs so that interventions can be made that instigate further change. Developing a theoretical understanding of the way in which systems function and change is important because it provides alternative options when they are required. This thesis has argued that climate change presents a huge challenge and that the electricity system will have to change dramatically to respond to this. Exploring which interventions are instigating change or what processes are not occurring is important because it identifies the areas in which further policy intervention is required.

It is the contention of this thesis that transition theory can be usefully applied in identifying policy gaps. It provides a lens for analysing the system impacts of a policy and a generalisability that enables researchers to identify patterns. It is important that the theory is constantly challenged, developed and refined but it is also necessary to begin to find ways of applying the understanding gained through this process to real-world challenges. This is a less explored area for transition research and it is hoped that this thesis has contributed towards this end.

The next section explores in more detail the potential areas of further work that would build on the contribution made here.

SECTION 9.6 ISSUES FOR FURTHER RESEARCH

SECTION 9.6.1 LONGER TIME PERIOD OF RESEARCH

The impacts of the FIT will keep developing as the scheme continues and the small-scale RE sectors find ways to work with the support it provides. A clear opportunity for further work in this area is to continue monitoring the ways in which the FIT impacts on system transition in the UK. The longer the scheme is analysed, the clearer the trends and themes that characterise its application will become. Therefore a useful contribution to this research, and to the understanding of the role of the FIT and the process of transition, would be to undertake similar work over a longer time period. The longer period would also allow slower-moving trends to emerge such as the impact of small-scale RE technologies on generator energy use. An objective of the FIT on introduction was to assist in the engagement of energy users with electricity and transition. Evaluating whether this has been achieved would require analysis over a longer period.

SECTION 9.6.2 INTERNATIONAL COMPARISONS

This thesis has focused specifically on the UK context but FIT mechanisms and electricity system transitions are occurring in many countries. An area of further work that would develop this research would be to provide international comparisons. A broader empirical base would allow for a strengthening, or challenging, of the findings within this research but may also provide fruitful opportunities for predicting future developments in the UK by looking at FIT schemes and system transitions at different stages of maturity.

SECTION 9.6.3 FURTHER IMPLEMENTATION OF THE ANALYTICAL FRAMEWORK

This research has adapted and applied an analytical framework developed by Kern and drawing on research by Geels and Schot (2007), Shackley and Green (2007), and Verbong and Geels (2007). Kern applies the framework to analysis of the Carbon Trust and this research applies it to the FIT. The framework provides some coherence and consistency in employing transition research to empirical studies and it could be used usefully in the analysis of other policy mechanisms designed for, or operating within, socio-technical system transition. The purpose of this research was to identify whether the nine processes drawn from the literature are occurring in relation to the FIT and to use the framework to structure complex empirical findings but further theoretical work could be undertaken to challenge whether the processes selected are the most incisive for analysing transitions.

SECTION 9.6.4 POTENTIAL ROLE FOR A SMALL-SCALE RENEWABLES COORDINATOR

One of the most interesting areas for further work that has emerged from the analysis in this thesis relates to the discussion around the coordination of project risks in Section 9.3.3 and illustrated in Figure 9.1. Each small-scale RE project has its own characteristics, risks and barriers (see Section 9.3.3). It is not possible for policy to effectively address all of these details but many of the issues relating to project delays are the result of relationships between stakeholders. For example, in the case of a hydro scheme the relationship between landowners on different banks of an impoundment; or between a developer and the Environment Agency; or between conservation organisations and local planners. Developers are generally adept at developing schemes but project delays often arise when communication between stakeholders breaks down. There is a potential coordinating role here for an organisation that could sit between the stakeholders and facilitate the relationships that drive a project. To the author’s knowledge there is no academic research that directly explores the options for this role and there is therefore an opportunity for further work.

There are a number of different actors who could potentially fill the coordinator role; the rest of this section presents four suggestions that present interesting cases for further work.

1- Office for Renewable Energy Deployment - The Office for Renewable Energy Deployment (ORED) at DECC states that it ‘*works closely with delivery partners and stakeholders to help accelerate deployment (of RE)’* (DECC, 2012k, p.1). This is the central Governmental organisation tasked with coordinating renewable energy delivery and they could therefore have an important role in addressing some of the barriers discussed in Section 9.3.3. However, they have a very wide remit and oversee delivery across the whole UK. Consequently, they may not be able to provide coordination that is specific to a project or geographical area. Further research could explore the work currently undertaken by ORED and the ways in which this could be improved to support projects at the smaller scale.

2- Local Authorities – LAs could be a very effective coordinator between the stakeholders in small-scale RE schemes. They should have a reasonable understanding of the natural resources in their area but they also operate at a level that allows for closer relationships with the stakeholders in small-scale RE projects compared to the high-level oversight of central Government bodies such as ORED. Roberts (2010) argues that LAs could be central actors in tackling climate change and delivering emissions reductions in their area because they hold influence that derives from the services they already deliver; the strategic roles they play; the regulatory influence they have to enforce national standards and directives; and the relationship they have with local residents, the voluntary and business sector and/or other public bodies in their area.

However, the suitability of LAs to fulfil a coordination role is dependant on the powers and resources they hold and this differs by authority and over time. The previous Labour Government made clear that LAs had a role in low-carbon projects as this quote indicates -

> *'The Government wants to encourage and empower local authorities to take additional action in tackling climate change, where they wish to do so. It believes that people should increasingly be able to look to their local authority not only to provide established services, but also to coordinate, tailor and drive the development of a low carbon economy in their area'* (DECC, 2009a, p. 94).

However, the EMR White Paper published in 2011 by the Coalition Government makes no mention of LAs as a delivery body for electricity projects of any kind (DECC, 2011b). This suggests that the Coalition have a different view of the role of LAs in electricity provision and to support this some of the powers and strategies that had been used to drive LA involvement have been removed since they came into power. This includes the removal of National Indicator 186[50] which provided a target for carbon reduction in the area and drove much of the LA activity in the RE sector (Audit Commission, 2009).

[å] Local Strategic Partnerships (LSPs), of which the LA was usually the lead body, were required to set targets for 35 of the 198 national indicators as part of their Local Area Agreements. Two-thirds of LSPs chose to sign up to national indicator 186 and in the two years it existed the Audit Commission argued that it had 'in many areas prompted concerted action for the first time' (Audit Commission, 2009, p.19).

Despite a shifting role for LAs there are examples of good practice in relation to RE development such as Birmingham City Council and Bristol City Council (see Chapter 7 Section 7.5.2.). Cornwall Council have also been very engaged with promoting the RE potential in the county through developing a database of local suppliers and contractors related to the solar PV industry (Cornwall Solar Directory, 2012), organising renewables conferences and meetings that advertise businesses and opportunities in the county (Cornwall Council, 2012b), developing renewable energy planning guidance notes for all four renewable FIT technologies (Cornwall Council, 2012a) and they have a program of renewables education for planning committees in the county who grant permission on planning applications under 5MW. It is difficult to evaluate what impact this activity has had on deployment but the developers that have worked with Cornwall Council, and who were interviewed for this research, indicated that the support the council provided was critical to delivering schemes (see Section 7.3.2.2 and Section 7.5.2).

Cornwall Council is a unique example of an authority with their own motivations for developing RE as part of an economic regeneration programme (Cornwall Council, 2012b). Cornwall also holds significant wind, solar, geothermal, biomass and wave energy resources that have facilitated a programme of RE development (Cornwall Council, 2012a). This programme may not be replicable for other LAs who do not have access to the same natural resources, or who have alternative economic strategies. However, the Cornwall example does illustrate the positive impact that a coordinating body can have on RE deployment in an area (see Chapter 7 Section 7.5.2).

There is an opportunity here for further work that explores the roles that different LAs have undertaken in RE development in their area and the impact this has had on practice. LA involvement in alternative but related sectors such as waste management could also contribute to this work. This could also be expanded to explore the changing role of LAs under the Coalition Government and the ways in which this has impacted on authorities' capacity to engage in RE development.

3- Commercial Project Coordinators – An alternative to LA coordination could come from the commercial sector. A commercial third party may be able to facilitate the relationships that often delay small-scale RE projects by deliberately placing themselves between stakeholders and building independent relationships. Commercial consultants already provide specific services (e.g. planning advice) but it is on a project-by-project basis. Further research might explore the potential for a more strategic commercial actor to build relationships and capacity within a geographical area such that all potential small-scale RE projects benefit.

One key advantage of a commercial operator is that they are not directly affected by political cycles or subject to the politically administered powers that control a LAs capacity. This allows for a little more freedom to operate and to build capacity over time. Several interviewees discussed the frustration of working with or within public bodies who were overly bureaucratic or slow-moving (Interview 14, 15, 21, 34 and 5) and commercial operators would be able to avoid this.

However, there are also a number of disadvantages to a commercial operator fulfilling the coordinator role. Firstly, they are unlikely to hold any regulatory influence or to have strong relationships with local residents, the voluntary sector, local businesses or public bodies. This lack of influence would limit the capacity for coordination. They would also require a return and would therefore add a cost to the delivery of a project which would have to be balanced against the benefits they are able to provide for project developers.

There is an opportunity for further work that reviews the activity of existing commercial consultants and identifies any areas in which further coordination could be provided.

4- DNOs - DNOs occupy a pivotal position in the electricity system and could potentially be incentivised to play a more active role in coordinating the development of small-scale RE on their distribution network. They are very closely regulated and have very specific duties that, currently, are not intended to include deliberate coordination of small-scale RE projects. They are also very well placed to co-ordinate demand response down to the household level, were the data availability, regulations and incentives in place – which they currently are not (Ward et al., 2012; Bolton and Foxon, 2010). DNOs are very able to respond when the incentives are there, as the So La BRISTOL project illustrates (see Chapter 7 Section 7.3.1). This project is funded by the Low Carbon Network Fund and includes multi-party coordination between Western Power Distribution, Bristol City Council, Siemens and the University of Bath (Western Power Distribution, 2012). It is a very different project to the coordination of small-scale RE but it shows that DNOs can undertake work that extends beyond the management of the network.

However, although DNOs are ideally placed geographically to coordinate activity, with a predefined network area, commercially they may be compromised by encouraging deployment of small-scale RE. Some of the distribution networks in the UK are owned by vertically integrated companies whose generation businesses are based around large-scale centralised plant. As discussed in Chapter 2, it may not be in the interests of these companies to drive small-scale RE deployment to any large degree. Exploring the regulatory and commercial arrangements concerning DNOs, and assessing their impact on the potential role for DNOs in coordinating small-scale RE activity, could be a constructive area for further research.

SECTION 9.6.5 CONCLUSION – FURTHER RESEARCH INTO SMALL-SCALE RE COORDINATORS

The FIT is an important development for all four FIT-technologies covered in this thesis and it has stabilised one of the key risks to developing a small-scale RE project. For the scheme to have a wider impact an increased diversity of technologies and scales must be delivered. This thesis argues that the intentional coordination of activity would result in a higher deployment rate for wind, hydro and AD projects. This would increase the diversity of technologies and realise more of the potential benefits of small-scale RE identified in Chapter 2 Section 2.3. Further academic research could be undertaken to explore how a coordinator might function; the advantages and disadvantages of introducing an additional actor into the RE sector; which stakeholders could best fill the role, building on the suggestions above; and review any examples of third party coordination in other related sectors.

SECTION 9.7 CONCLUDING REMARKS

The research question that this thesis answers is - what is the role of the small-scale feed-in tariff in electricity system transition in the UK? It has been argued that the electricity system is in a period of transition that is driven by legal targets for carbon reduction and renewable energy. There are many potential combinations of technologies, practices and actor-roles that could drive the necessary transition and constitute a low-carbon system. This thesis has argued that small-scale RE technologies should play a significant role in the future system and that they have a number of benefits that would assist in the transition process itself. The FIT is the policy mechanism designed to deliver small-scale RE in the UK and it has therefore provided the focus for this research.

A transition is a shift in the way in which a societal function is fulfilled within a socio-technical system. As argued in Chapter 8, although climate change is a huge issue that will require unprecedented action to address, it is not driving an immediate 'avalanche' transition and change is likely to occur over decades. As such, the period with which this thesis is concerned (two years and five months) is very short within the context of transition. However, the research has highlighted the *emergent* impacts that the FIT is having on the system and it has discussed the significance of those impacts for achieving a transition. The FIT has had two main roles in the process of electricity system transition since it was introduced.

The first main role of the FIT in electricity system transition has been to kick-start the solar PV industry, and to a lesser degree small wind and AD, such that developers and installers have begun to innovate and achieve increasing returns to adoption. Whatever the future is for each of the FIT technologies, they all require an initial burst of activity in order to overcome the barriers to development. Once this is achieved then the advantages and disadvantages of each technology can be explored through experience. RE policy in the UK before the FIT did not provide the support necessary to develop small-scale RE at a scale large enough to experiment and innovate. The FIT has started to do this for solar PV and this could be significant for electricity system transition going forwards.

The second major role of the FIT in transition is to provide the support required to demonstrate that an alternative to large-scale, centralised technologies is possible. The scheme has delivered a large number of solar PV installations and an unprecedented number of new entrants within a very short space of time. Although the total FIT capacity is modest in relation to the incumbent large-scale technologies the scheme has shown that decentralised capacity can be deployed quickly if the support is sufficient. A characteristic of a system locked-in to a particular pathway, as has been the case of electricity since privatisation of the industry, is that alternative approaches are perceived to be too challenging. The FIT has been controversial and is seen by many regime actors to be expensive and inefficient but it has undoubtedly informed the electricity policy debate through demonstrating that different generation options are available and deployable.

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Appendices

APPENDIX 1 SAMPLE INTERVIEW QUESTIONS

These are the baseline questions used for each interview. They were adapted to each stakeholder. They were used as a basis for discussion but additional topics/questions were often covered.

1. Thankyou for coming, is this a very busy time for you?
2. What impact has the FIT had on your business?
3. What has been your experience of the administration/management of the scheme by Ofgem? E.g. levelisation.
4. Do you think the FIT has stimulated innovation of technology or investment?
5. What impact have the recent changes to the FIT had on your business?
6. Has the introduction of small-scale RE had any impact on the distribution network?
7. How will management of the distribution network develop in the future?
8. Do you think that the FIT is impacting on other policy mechanisms/design at DECC?
9. Have new entrants in the FIT supply-chain and new FIT generators had an impact on your business? Or on the electricity system?
10. What could be done to improve the FIT?

APPENDIX 2 SAMPLE TRANSCRIPT

Interview 4 – Head of Policy, Big 6 Electricity Supplier

J – Thankyou for coming to meet me today. I imagine this is a very busy time for you?

Interviewee 4 (I4) – There’s so much going on because of the PV review at the moment with the proposal that installs after Sunday get the lower rate. So the amount of installations that have been going on recently has been amazing, I think 20,000 last week. Considering 20,000 was the number of installs for the whole of 2010 it's just amazing. So everyone is just trying to install while they can. We've had some problems with the MCS installation database because there's so many people trying to get registrations on to there it's all slowing up. So we're trying to speak to DECC and get them on board with a contingency plan because if there's that many being installed you could have ten or twenty thousand people left out of pocket when they were expecting that they would be fine.

J – What are DECC saying about that?

I4 – We raised it yesterday and we're waiting to hear back. But we're having problems, you know we're quite a big player in the market but we're only less than 2% of the installs, it's a very fragmented market. So this is being repeated everywhere. One of the things we've done is concentrate really hard on all the customers we've made promises to and ensure that we got those installations in this week so there's lots of planning going on for that, getting planning there on time or making sure you've got the right people in the right place. We've had a lot of people involved on that. So we've taken some of the people who normally register the installs off to do some of that work thinking once all the work's been done you can have them working on registering the installs. But this week you just cant get on the database, its a bit of a nightmare and I'm sure that's been repeated everywhere.

J – Yes I've heard similar things from installers, bringing extra people in.

I4 – I don't know where they've all come from.

J – One installer I spoke to has brought in staff from Belgium.

I4 – Yes people are coming from all over Europe.

J – Could you say what impact the FIT has had on your business?

I4 – As I was saying there have been two kinds of impact. One because we're a large electricity supplier, through our licence conditions we have to administer the FIT. So our customers who come to us who have installed solar panels they'll come to us, we have to do a bunch of checks. In some cases they are mandated by government; they are mandated by Ofgem. Some of those checks, our customers think you're treating us like criminals even though we’ve been your customer fro 20 years, why do you have to do this? So that’s had a bit of an impact. We’ve probably got a team of about 50 full-time, we’ve probably got about 14 or 15 thousand customers who we are paying FIT to so there’s been a massive piece of work done there to make those payments, arranging all of that. The amount of payments we make out each year is huge as well so because the FIT is shared out based on the amount of electricity supply you have. In the FIT process there is a levelisation process where the money is spread between all the suppliers every 3 months. I think the last 3 months statement we had to do, that was more money than the whole 1st year of FIT so its increasing so much. This year we’re probably spending out 15 million pounds, next year it will probably be double that, perhaps even more so it’s quite a big impact financially which then goes onto customers bills.

J – Are you happy with the way the levelisation process is administered by Ofgem?

I4 – Its just part of what you have to do if you want to be an electricity supplier I suppose so it’s fair enough. We probably have slightly fewer payments to make than our market share because some of the smaller suppliers, non-mandatory FITs suppliers have come in and they take much more than their market share so it may be a problem for them. One of the large suppliers is happy to pay FIT payments to anyone and quite a lot of the funded rent-a-roof schemes, they pay the FITs for. So they’re a bit out of kilter as well. I think at the moment, this is a question Ofgem had for all the suppliers because we were still all working on quite basic manual systems; it would be too much of a burden to do it more so I think the cash flow hit is not as bad as the impact of having to do all that reporting. On that side of the business that’s the impact. On the other side we got involved in microgeneration in 2008 when we bought a company called (X) which throughout the 2000s it was probably in the top 2 or 3 solar businesses in the UK. For most of the noughties most of their sales were into the business sector rather than the domestic sector. Last year there was a bit of a journey to try and create more residential installation capacity. I’d say now we’re probably one of the top 5 or 10 players in the market. Although having said that we’ve still got a pretty small market share. Some of the things that we’ve done, one of the biggest innovations has been financial, that’s been one of the key things why FITs have been a far greater success than anyone imagined. But the areas of growth for us have been things like growing residential, designing rent-a-roof type free solar, that’s been a lot harder than we thought. We don’t understand how some of the more successful companies in that have done that so well actually, so easily. We found the lease process was a real pain. One of the major projects we did this year was we worked with (a large company) who have a massive factory at (X) where they, I think its the biggest (X) manufacturing plant in the UK. So what we've done there is funded a 4MW install next to one of their massive car parks. And that goes into their factory, none of the power is exported. That was done in July.

J – So you're business is quite diverse.

I4 – Yes I think our strengths are, we've found the domestic market is just so fragmented and the only way that a large company can differentiate itself and get real volume is in free solar, things like finance models for businesses where you can bring together a package for financiers, you are someone they trust in terms of quality of installations, the kit you use etc. But a lot of that has been taken away by the change to the FIT review. So we've said we changed our business strategy 3 times this year actually in that business which is crazy.

J –You touched on innovation earlier. Do you think the FIT has achieved innovation in technology and investment?

I4 – I think if you look at the technologies within the FIT you've got solar wind hydro a bit of microCHP but it's not the key focus. The problem with hydro is a project is going to take you bloody ages to get planning in place, get your permissions, EA permissions all that, that's a couple of years, the finance, you build it. There's not that many great sites so it's not going to be massive. Wind requires getting planning and all of that so its going to take a couple of years. Solar on people's roofs you can just put on so easily and roll so much of it out. So the FIT has been dominated by solar. I think there's probably more solar under the FIT than the government would like actually but I think they did think that solar would be the key beneficiary. In terms of the finance, back in 2009 there was a danger that people were having to spend 13 or 14 grand on a system and they're only making a 5% return, will they be arsed to do it? Probably not really. So we always said that the returns had to be high enough to permit financing. The government said we want financing to occur but I think its become obvious that if you can finance for 1MW installations then you can finance a billion trillion MW so once that's out of the bag, that's it. If you're operating a policy that has a cap on its budget then that's no good. So whilst they wanted financial innovation to happen...

When we went into in early 2010 the sort of financing that we foresaw happening was basically retail banks offering retail loans to people. It would be a 25-year ‘pay as you save’ type loan with the FIT backing it up. And we spent a lot of time talking to banks seeing if we could make that work and I think banks didn’t really want to take the credit risk. When we looked at something like rent-a-roof type financing, when we first looked at it we thought the money’s quite tight anyway, the returns are quite tight anyway, but if you’re giving up 10% of your revenue to the customer as their rent for free electricity then it doesn’t all quite add up unless you can make a real good saving on economies of scale. So some of the innovators in that like a Shade Greener who’ve now done their 10 thousandth installation. If you want to talk to someone about innovation talk to someone there.

J – I’ve spoken to (X, another aggregator) but that was early on in my research.

I4 – A shade greener were based in Yorkshire somewhere, so not the ideal place in terms of installation but what they said was if you’ve got enough roof space for a 3.3kw system, because that was the minimum size that was a sweet spot for the returns. You want plum south facing and you’re within an hour of our warehouse in Rotherham or wherever then we’ll give you free solar. And they got lots. So what they managed to do was to sign a big order with a Chinese panel manufacturer, I think he ordered 6000 installs worth, at once, 20MW which was quite a big order for the UK at the time. So he got quite a good price on that and got his prices down because he was doing all his work in one area within an hour of the base so they could get the economies of scale and do lots of work at one time. And they concentrated on the sweet spot so they did well. So I think what’s happened since then as well is the financial innovation, if you look at the overall returns, and we’ve done something similar and set up a special purpose vehicle to have all your solar assets in and you look to sell the SPV, if you can make an acceptable rate of return in that SPV, then you’ll have people like pension funds wanting to buy that eventually. If you can get an SPV where you get a loan in there so your equity in there is only 20 – 25% you can gear, then actually you’ve got less equity in there, and you gear your returns so the little bit of equity in there you actually make 15 – 20% returns and that’s quite good. Also what happened was these VCT trusts and a lot of money flooded into that. So people that are on a higher rate of tax invested in these VCTs and its tax-free so it’s a 40% gain on your tax. So that’s been another way that money has flooded into some of these funds that wanted to buy into solar funds. A lot of it has been financial innovation, that's what's been leading the charge. That was behind a lot of the large-scale solar parks. Large scale solar at 29p, that was just amazing. It was amazing which is why you got lots of them but also it was clever financing that made that happen as well.

J – What's happened to that more innovative side of investment into solar since the changes were announced?

I4 – I think investors are quite nervous beasts at the best of times so when something like this happens a lot of people who are trying to put through deals at the time think a lot of that just went away. Banks were just like 'this is too much. I don't understand it, I don't spend all my time listening to green policy but you told me this was safe and now its not anymore so for that reason I'm out'. So I think a lot of the belief's gone and what's going to happen for the next 3 or 4 months up to the 1st April where you've got more than one installation to take some more steam out of the funded market, what they're proposing is a 20% discount on the tariff if you own more than one install so after April I think that will be dead. Up until April there will be a lot of people taking a portfolio approach to this who still have stock or have stock on the way from China and they have paid for it, they're going to make a massive loss if they don't install it. At 21p they'll make a bit of a loss but if you look at the whole portfolio they've got 90% of their portfolio at 43p and 10% at 21. You're making more on this bit than you thought so actually you can afford a bit of a loss on this bit but its better than having all these panels that you cant do anything with. So you'll still see stuff happening to April then after April there will be a massive slow down.

J – You said you tried the funded solar but its hard because the returns are narrow?

I4 – That's what we thought at first. Returns are quite narrow. If you look at PV at 43 or 41 pence on a 2.5kw site, well placed, you're looking at basically saying 900 pounds from generation, 130 from saved electricity then 30 or 40 quid from the export. So if you look at it the saved electricity is quite a big part of your return but its only 10%. So unless you can get decent economies of scale on the other side you're losing this chunk of revenue so you just need to make the other side of the equation add up.

J – But I suppose that's difficult to do if you've got quite an dispersed customer base?

I4 – We've found that actually when we started advertising this free solar you get shit loads of people apply but then once you speak to them you find out that their roof isn't south facing, they don't own their house, there's problems. The roof's not big enough. So you explain the 25-year lease and they say 'god, I don't want to do that.' And then you've got to get their mortgage lenders consent and all that kind of stuff. So it can take months to work through that. You're spending a fortune working through that. We've had a lot of issues getting a big uptake on this and we're amazed how A Shade Greener could knock 10 thousand out.

J – What physical impacts has the number of installations had on the network?

I4 – If you look at the size of our position, a few domestic solar installs here and there doesn't touch the sides. Its not even within the usual, for electricity generation if you can get your forecast down to a few percent then you're world leading so I don't think you've got enough there to really worry about it. At the moment the vast majority of everything that's installed, the power just leaks back onto the grid because it's not settled. There's really good reasons why it's not settled, because the infrastructure and systems aren't there for most electricity companies to do that yet until smart metering comes into place.

J – So how is that power managed?

I4 – The electricity goes back into the grid and its allocated back to you through correction factors anyway. So the way electricity is settled is you take out all the half hourly metered stuff because you know what that is then you have a bit of a guess. You have like shapes for each person and you've got their general volume so it's all kind of estimated anyway. So it might mess up that estimation a little bit but I heard someone say recently there's about 200,000 PV installs in the UK, that seems a bit high to me I thought it was more like 150, 160 thousand but out of 25 million houses it's not a lot. So it's going to be lost in the margins really. Again we're not a DNO ourselves so we don't see the effect but unless you have a close where every single house has PV panels, and even then you wouldn't even see an issue because the wire into each house can take up to 20kw load. If this is only 2 or 3 kW. Someone whacking a kettle on for 30 seconds, that's 2.5kw coming the other way. So a lot of these systems, that's the very maximum they're ever going to be doing. I'm not much of an electrical engineer haha.

J – You mentioned that you had to change your business approach 3 times, how did it change?

I4 – Originally, when we first started our solar business it was looking at straight sells to households in the summer of last year. There were quite a few new free solar schemes out there so we had to look at how that would work, which was change 1. Change 2 was around the end of last year, there were a lot of the large scale solar projects so we were looking closely at what others were doing and talking to a lot of people about those and how we could make those work. We've found the domestic market is just so fragmented and the only way that a large company can differentiate itself and get real volume is what we saw happening in free solar. So then we looked at what's now your sweet spot, so a bit of domestic but we're also working on these big social housing schemes. So you do it with a council and put up panels on those schemes. A lot of those councils, as panel prices dropped, they got greedy so a lot of them could have got a lot of installs installed at the start of last year but they were looking around and thinking 'hang on, there's a lot of FIT money here.' They were demanding cashback of £1000 per install so they were negotiating for the best deal they could get and went out to tender and all that kind of stuff so they totally missed the boat. So not much of that happened. That was the thing that the government feared, a big roll out of those. After the changes above 50kw, 40-50kw systems became a bit of a sweet spot. So we were talking to a lot of people about those as well but they seemed to have gone down the pan now as well. So now the only viable business model we can see going forward after April is straight sell to customers, which is where the government has always wanted it be. Greg Barker states that's where his vision for it is so that's where it's headed. So we've got to get better at selling that sort of proposition.

J – What do you think about the energy efficiency requirement that's part of the review?

I4 – Back in 2009 when it was first proposed we said we shouldn't because demand, there's not tonnes of demand for PV at the moment, you shouldn't put one more thing in the way. So now, actually we probably agree you should be doing the energy efficiency first. So we agree with link but EPC C is way too tough. That will just destroy the market. Only 10 or 15% of people are already there. To bring yourself up to that level is another 5, 7, 10 thousand pounds so we just don't see people doing that and then forking out 10 thousand pounds for their solar panels and we think the link with the green deal will probably be good because it will help drive demand for green deal because that could be worth it. But green deal wont be here until October and from April to October its quite a stretch to have to say 'right install this, you'll have to take out green deal in the next year or instead of 21p you'll get 9p but we cant tell you what green deal is going to look like or what you're possibly going to get or how much you'll have to fork out for that yourself.' So that's not going to sell so we've told DECC that we need something in the interim so maybe just the basic measure of cavity wall and loft which are cheap or free in a lot of cases for people. If you do those in the interim you can link it to green deal once its out. So it makes sense. I think you'll find that a lot of people that have solar panels do take great interest in their energy use because they're interested in how much they're making so they're always looking at their meters saying how much did we make today but they're always interested in saying 'if I export this power I'll get 3p for it but if I use it on site I'll be saving 14 p so lets see if I can use my energy at the right time so during the day its making the most of it.

J – I'm interested in the link between green deal and FIT. Do you think the FIT has impacted on other policies, or policy design, at DECC?

I4 – Well I think even in FITs going forward they're going to be keeping a much closer eye on what's going on. They've always had the tools available to do that but they've never really used them. So cast your mind back why FIT happened and its just standing in the department, what happened was in late 2008 there was an amendment to an energy act for a private members bill. Some of the Labour MPs revolted, the Tories and the Lib-Dems supported the amendment. It seemed that labour was going to lose and their energy act was going to come down if they lost this so they agreed to put provisions in there for a FIT and a RHI. So they never wanted to do the FIT in the first place. The Labour Government and DECC never wanted it but it was done over their dead body. They didn't put enough effort and resources into the team I don't think to make it a success. So they got it through, they did get more positive about it as it was going through as Ed Miliband became secretary of state and he was really behind it but within the department there wasn't really very much enthusiasm for it and then once it went live they only had a couple of civil servants in that team, they weren't very engaged with it really. And they just thought we'll put it into place and just forget about it. Now its coming in and kicking them on the arse because its costing the budget and there’s a lot more focus on it from a very senior level in DECC and Greg barker, there’s 2 things he’s particularly keen on, green deal and solar so he’s taken a lot more attention of it as well. So going forward they’ll be doing it a lot tighter. Green deal because it is the flagship policy, there’s probably at least 50 people in DECC working on it at the moment. It won’t continue at that level once it starts but there’s going to be so much focus on it. Hopefully they’ll have some skin in the game themselves through involvement in the green deal finance company. And also the 200 million quid of incentives that they’ve brought forward to make it work.

J – Do you think that will settle investors or companies such as yours if they have skin in the game?

I4 – Yes definitely, it will give us more comfort that they’ll make it work. To an extent, it’s in an energy company’s interest to make green deal work anyway because we need it to work if we’ve got half a chance of meeting our Energy Company Obligation so we’ve got a big incentive to make it work as well.

J – What has been the impact of new entrants on the generation side and supply chain?

I4 – Well I suppose its good in terms of democratising power generation especially in domestic scale, that’s great. There’s a lot of talk about new entry to the energy market but its quite serious stuff, but even a relatively minor power station that’s going to deliver half a percent of the UK’s power will cost a billion pounds. So you can’t just wake up one morning and say I’m going to build a billion pound power station, you’ve got to be someone quite serious to do that and similarly in energy supply. The sorts of commitments that you’ve got to put in place so your customers aren’t left in the lurch, you have to put forward deposits and have decent credit risk and all that otherwise you’re not fit to operate in that market. So it’s swings and roundabouts really. So we’d welcome more people being involved in the market but there are, not barriers as such, but I guess its not like opening a corner shop or something. There are serious consequences required to go into it.

J – Do you think there’s an opportunity for new entry for aggregators or ESCOs? Are they coming forward or if not why not?

I4 – My previous job in (company X) was working in RE purchasing so I talked to all the independent wind farm developers and all that and we'd find that because we've got such big targets and such a big amount of electricity to deal with and a limited amount of resource in our teams we actually want to deal with people who can make a difference to our final position. So we did work with Smartest and other aggregators quite a lot so in terms of if people are too small for us to deal with because it would take too much effort or we didn't have standardised contracts set up to deal in that small part of the market, we'd send them on to Smartest and Tradelink. We'd work with them to buy their ROCs or LECs which they buy from those little generators. So there's a definite role for those guys in this market. Especially with the midsize generators, like residential scale we can deal with but I don't think we find it particularly easy to deal with small businesses. There's a gap between what we have to do under FIT up to about 30kW up to about 10MW we find that really difficult to deal with. There's a natural role for lots of companies to come in there.

J – Do you think they will come forward?

I4 – I'm surprised there's not a couple more really but even setting up something like Smartest. They must have to have, they're backed by Mahinda (?), a big Japanese company, so they still need to have quite a decent balance sheet to help with all those commitments and generally if you're developing a 5MW windfarm, 2 turbines. Unless you're lucky enough to have 7,8, 10 million pounds to fund that then what you're going to have to do is you're still going to have to fund 2 or 3 million yourself then you're going to have to go to the bank for at least 75%. When you go to the bank the bank will say who are you for a start then they'll be interested to know how you'll pay back your loan. If you've got a contract from someone saying I'll buy your power or ROCs for the next 10 years that's fine. But then what they'll want to do is look at whether the person signing that contract will be around in 10 years to do that. So I think a lot of these smaller companies, and especially someone like Tradelink, they cant sign a long term contract because they don't have the credit standing that banks require for those small companies to get their loans. I think Smartest had some of those problems when they were setting up so a lot of Smartest contracts were 1 or 2 years with generators.

J – How do you think the distribution network will develop in the future?

I4 – I think 10 years time it's going to be very very interesting, very different from what's now. We think over the next 10 years you're going to have a massive change in energy. We talk about it all the time, we like to say that despite all the changes that have happened in the energy business in the UK in the last 50 years, conversion from town gas to gas network, change from coal to nuclear and gas, privatisation of the gas and electricity industries. That's a lot of change in the business, you always feel like it's changing. If you're a customer nothing has really changed for like 100 years. Basically what happens is every 3 months you might get you meter read or not, you'll get sent a bill and it might be off a real meter reading, it might be off and estimate. You'll pay it, the name at the top of the bill might change but from a customer's perspective do they really care. It's been like that forever. But in 10 years time everyone's going to have a smart meter, there's all this move to low carbon energy, so you're insulating peoples houses, giving people green deal all that. People might have microgeneration so they're selling electricity back to the grid. You have your smart meter, you do things like, you might have smart plugs, and set up and sign a deal with someone so if the wind drops all of a sudden and the grid needs power, instead of phoning First Hydro and getting someone to press a button and let water down a sluice, instead you can just turn everyone's freezers off for 10 minutes, that could be a clever way to go. I see a lot of that happening. So you've got a move to EVs, a lot of electrification of heat. So I think the next 10 to 15 years in the energy industry, its going to be very very exciting, a lot of change. If companies don't think about this and blunder into it they're in for a shocker really. So we've been thinking about this for quite a long time. We've got quite a lot of people whose day jobs it is to think about how we make this transition and develop propositions around smart metering, around smart homes.

J – That does imply a far higher level of consumer engagement, how might that be encouraged?

I4 – You've just got to make it easy for people. If you make it easy for people and you engage with them, so you've got people that engage through social networking sites nowadays. If you can send messages through their TVs or through their smart phones you can make it a lot easier to do. Then that's going to drive the change. But step 1 is to get people engaged. But I think all this technology and all these changes will increase that engagement.

J – Thankyou so much for your input. It’s been fascinating to hear your account. Just finally, what improvements could be made to the FIT scheme?

I4 – If they go too harsh then they’ll just kill it in April but if they’re pragmatic there’ll get more than they want and then sort of go into October and wait and see. I think the 21p tariff has been set at around £3300/kw installed. If you Google FIT one of the sponsored links is ‘buy 4kw for 10 grand’. That’s 2500 pounds per kW. If they can do that then that implies a much lower FIT and a higher return. And then a lot of people have been advertising saying under the new tariffs. Its 4.5, 5% return but whack on inflation that’s running at 5% a year at the moment but actually over the long term its probably 3% so you’re up to 7.5 or 8%. If you’re a higher rate taxpayer, that goes up to needing a 12% equivalent investment. It will be better putting solar panels on your roof. That’s still going to be appealing. That’s our worry because what we’re interested in at (company X) is having a long term sustainable solar market, so we’re not just interested in making a quick buck and whacking in a few panels and disappearing, we still want to be installing panels as part of whole house solutions in 5 or 10 years time. But for green deal they have managed to find 200 million quid at the drop of a hat. If the government wanted to put more into it they could. But that’s one thing putting more into that when people are making 15, 20% return and everyone’s making a killing. First what they want to do is return the industry to an even footing where everyone’s making reasonable returns and they’re not excessive and then from that point think about asking for more.