Decentralised electricity and its implications for the governance of UK energy security

Submitted by John Oakley Allen to the University of Exeter as a thesis for the degree of Doctor of Philosophy in Geography.

September 2014

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

The GB electricity system is in a state of change, both physically and operationally. The future of the electricity system needs to be low carbon and secure. Current system structures revolve around large-scale centralised generation to deliver this security. This thesis argues that with a broad definition of energy security, which reflects the future needs of the electricity system, a decentralised approach would be more beneficial to deliver these needs. This thesis identifies the governance processes that make up current energy security and evaluates how these might change in a system of decentralised electricity.

The research consists of 31 in-depth interviews with key stakeholders of the electricity system from the government, regulatory, market and civil society based actor groups. In addition to this, the research utilised a secondary analysis of consultation responses and Government publications. This thesis uses multi-layer perspective theory to interpret the transition from a centralised to decentralised electricity system. In addition to the multi-layer perspective, an advancement of the governance perspective was also required. This develops the understanding of the changes to the actor relationships rules and the incentives of a decentralised electricity system.

This research developed for key findings. Firstly, a decentralised electricity future would introduce a larger number of small investors, who in a centralised system would not exist. The second key point is, the UK Government is responsible for security of supply and their actions are focused on centralised electricity technologies. The third point is that energy security (in its boarder definition) is the responsibility of a network of actors working together. The fourth point is that current energy security is incorrectly dominated by supply meeting demand.

The outcome of the research is that a decentralised electricity system would be beneficial to the broader concept of energy security which is used in this thesis.

Table of Contents

List of Figures

List of Tables

Acronyms

AC	Alternating Current
AEP	Association of Electricity producers
BERR	Business, Enterprise and Regulatory Reform
BETTA	British Electricity Trading and Transmission Arrangements
CCC	Committee on Climate Change
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CEGB	Central Electricity Generating Board
CERT	Carbon Emission Reduction Target
CRC	Carbon Reduction Commitment
DC	Direct Current
DECC	Department of Energy and Climate Change
DNC	Declared Net Capacity
DNO	Distribution Network Operator
DSR	Demand Side Response
DTI	Department of Trade and Industry
ECCC	Energy and Climate Change Committee
EMR	Electricity Market Reform
ETS	Emissions Trading Scheme
EU	European Union
FIT	Feed-in tariff
GB	Great Britain
GEMA	Gas and Electricity Markets Authority
IEA	International Energy Agency
IED	Industrial Emissions Directive
JESS	Joint Energy Security of Supply
LCF	Levy Control Framework
LCPD	Large Combustion Plant Directive
LULUCF	Land use, land-use change and forestry
NETA	New Electricity Trading Arrangements
OFFER	Office of Electricity Regulation
OFGAS	Office of Gas Supplies
Ofgem	Office of Gas and Electricity Markets
ONS	Office for National Statistics
PIU	Performance and Innovation Unit
PPA	Power Purchase Agreement
REC	Regional Electricity Companies
RO	Renewables Obligation
RPI	Retail Price Index
SSE	Scottish and Southern Energy
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
VAT	Value Added Tax

1 Introduction

The UK Government has called for a reduction in carbon emissions of 80% by 2050 from 1990 levels. This will have a major impact on the energy sector as energy supply contributes around 40% of the UK's total emissions (DECC, 2013a). In addition to this, there are a number of other drivers forcing change, including: the recent downturn in the economy coupled with escalating fuel prices, the increase in energy's links with the multi-polar world and concerns over resource depletion.

Therefore, future supply will need to take these aspects into account. The Government has identified the need for a low carbon system with a set of goals, targets and budgets for carbon emissions, one aspect of which is the development of renewable energy technology (DECC, 2012n).

There has been a steady increase in the level of demand for electricity over the last few decades and demand is set to increase again with the prospect of electrifying the heat and transport industries. However, between 2011 and 2013 the demand level has fallen. Further to this, there are as yet untapped efficiency gains, which could be unlocked through the demand side and with it the activation of the distribution networks. Therefore, the future will need to allow for not only a changing supply industry, but also a change to the demand side.

This thesis is looking at the changes a decentralised electricity system may bring to the current model of electricity generation focussing on the governance of energy security. The thesis has developed two research questions:

- How will a decentralised electricity system change the governance of energy security?
- Who is responsible for energy security (not just supply)?

In order to achieve this, the thesis will need to set out what it means by certain terminology, namely decentralised electricity, energy security and governance.

A decentralised electricity system, for the purpose of this thesis, includes two dimensions: the technological aspect (including generation size and locality) and the aspect of ownership (where a large number of smaller stakeholders are able to access the electricity system):

- The generation plant would be either connected to the distribution network or off grid, at a location close to the point of use.

- A decentralised electricity system has a greater number of stakeholders with ownership of infrastructure, of different scales and dispersed geography.

However, in literature the term 'decentralised electricity' is not often used. In order to classify the situation, alternative terminology needs to be found, such as, 'embedded' and 'distributed' generation. Although decentralised electricity generation is often synonymous with renewable generation it is not a prerequisite. However, what is evident is that much of the discussion of decentralised electricity generation does assume variable power production. This is often linked to some renewable electricity generation (wind and solar) and identifies, technologically a security of supply issue.

E*nergy security* is far more complex than simply short-term supply operations and a definition to encompass all aspects is required. The UK Government has identified energy security as one of the major challenges to the UK energy system. Although, it is only recently that the UK Government has provided a definition of energy security:

> *"ensuring that consumers have access to the energy services they need (physical security) at prices that avoid excessive volatility" (DECC 2012o pg. 5).*

In order to provide a comprehensive definition of energy security an overview of the different dimensions of energy security need to be explored. These dimensions have been broken down to categories, including: firstly, the drivers, which encompass the external influences which act on the electricity system to create change; secondly, the issues which set out how the energy system can be affected by the drivers; thirdly, the dimensions of risk which is affected by one or more of the issues; and finally the impacts of the risks. These four categories of energy security together provide an overview of energy security and ultimately help provide a definition of energy security . From these dimensions if follows that the requirements of energy security are:

- The provision of reliable energy supplies for primary fuels and their delivery.
- The energy system needs to be flexible and dynamic in order to respond to unforeseen future changes.
- There should be protection for the fuel vulnerable in the case of energy price rises.
- The cost of maintaining energy security does not undermine the economy.

In order to achieve these requirements for energy security, suitable governance processes need to be established. The governance of the electricity system, for the purpose of this thesis, is defined with two interlinked aspects: the organisation of stakeholders within the electricity system as well as the rules and incentives which enable the system to achieve the desired outcome.

As a result of this boarder definition of energy security could mean a change to the structure of the electricity system from the predominantly centralised operation at present, to a decentralised, low carbon system. This change to the structure of the electricity system would inevitably mean a change to the governance processes in which it operates. This thesis will discuss whether these modified governance processes are better placed to meet the energy security challenge for the UK.

An important note to make in this thesis is the difference between the United Kingdom and Great Britain. GB includes England, Scotland and Wales and as such concerns the majority of the discussion of the thesis. This includes aspects such as the GB electricity markets and the role of the system operator. The UK includes England, Scotland, Wales and Northern Ireland, officially known as United Kingdom of Great Britain and Northern Ireland. The use of the UK relates to the UK Government and many of the policies, targets and goals which have been set.

This thesis has been set out such that the initial chapter (chapter 2) discusses the development of the UK electricity system after 1990. It begins by identifying the privatisation of the UK energy system. It discusses the 'dash for gas' and the development of retail market choice for consumers. It then examines the wholesale market approach for electricity, starting with the Electricity Pool to New Electricity Trading Arrangements (NETA), British Electricity Trading and Transmission Arrangements (BETTA) and the use of Purchase Power Agreements. From this, chapter 2 identifies the changes Electricity Market Reform will bring to the UK electricity market. Over the last two decades the electricity system has also seen a great deal of change to the regulation of the distribution and transmission networks, from RPI-X price controls to RIIO.

Chapter 2 then sets out the policy context, including the UK Government goals of Climate Change, Affordability and Energy Security. It identifies the targets set by the UK Government including carbon reduction and the renewable energy targets. Chapter 2 concludes by identifying the key stakeholders involved in the electricity system. This includes DECC, the Treasury, Ofgem, transmission network operators, distribution network operators, the System Operator, ELEXON, energy supply companies, consumers and other groups such as commons select committee and the Committee on Climate Change.

By establishing the development of the electricity system from 1990 to present, Chapter 3 can then set out the future. This includes the projected changes to demand from the electrification of heat and transport, the possible increase in demand side response and the possible dramatic increase in the level of storage. In addition to the potential changes in demand are the possible impacts from the supply side, such as investment in electricity generation and the procurement of transitional fuels. Chapter 3 then looks at the future of both the transmission and distribution networks, the introduction of a smarter electricity grid and greater interconnection to Europe.

This inevitably leads to a discussion of the geopolitical influences. Current geopolitical aspects for energy security can include the uneven distribution of primary resources specifically for oil and gas, meaning countries with lower resources can be more exposed to global prices and supply interruption[1]. In addition to this there is a requirement for specialized knowledge and skills such as for the operation and decommissioning of nuclear generation. Future geopolitics could also bring in further complications such as the development of a global infrastructure for smart grids. What is clear from this is that each global state is interconnected; therefore, greater security internationally would lead to greater security for the UK. Although, each state will make different decisions and have different opinions on the future of their electricity system. These decisions can be primarily political, however, it can be considered that each state would aim to avoid harming its own security of supply (Skea and Ekins, 2014). Therefore, due to lack of time and space this additional complexity of geopolitics means that this thesis will be focusing on the UK energy system. However this has been discussed in greater detail in Ekins and Watson UK Energy in a Global Context (Ekins and Watson, 2014) and in Malcolm Wicks Energy Security: A National Challenge in a Changing World (Wicks, 2009).

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[1] These issues can be combatted by the level of national storage (see section 3.2.1.4)

The fourth chapter develops further the energy security concept. It does this by looking more deeply at the evolution of energy security in UK Government policy and how it has changed: from being an issue of supply to be developed into a more rounded concept featuring an affordability aspect along with it. However, the definition provided by Government does not provide a complete picture of energy security. Therefore, as said above chapter four breaks down the concept of energy security into different dimensions including: the Drivers, Issues, Risks and the Impacts. By identifying each aspect this thesis is able to isolate a set of 'requirements' the energy system needs to meet in order to provide energy security in its wider sense.

Chapter 5 defines a decentralised electricity system and its impacts on energy security. It explains the different aspects of a decentralised electricity system (including: the policies, economic and social aspects). It then delves further into the energy security and the technical and non-technical impacts of a decentralised electricity system including flexibility, diversity, dependence on insecure supplies, demand and supply, and the economics of decentralisation.

Having an understanding of the electricity system, energy security and decentralised electricity, set out in the first chapters this thesis then goes on to review the move to a low carbon system through the transition literature. This begins by discussing the current lock in to centralisation and then the different transition theories. It takes the multi layer perspective as a good grounding for the discussion of a move to a low carbon, decentralised electricity system. However, what is identified as lacking from this model is the required changes to the governance processes needed for a transition. Therefore, chapter five identifies the various governance theories and approaches and discusses the relationships of each of the main stakeholder groups involved in the GB electricity system.

From each of these defining chapters, chapter 6 then sets out the aims and objectives of the thesis. From this it identifies the methodology that is used in order to achieve these objectives including the primary research technique and the analysis of the data.

The final four chapters of this thesis are the findings of the research. Chapter seven is a discussion of the move to a low carbon decentralised electricity. It discusses the governance needed to achieve this, as well as the timescales involved. It shows how a low carbon, decentralised electricity system can be implemented gradually but in relatively short timescale. It also argues that a low carbon, centralised system is a large step change resulting from the necessity of large power plants. This chapter goes on further to discuss the skills required for the move to a low carbon system. It identifies that a decentralised electricity system would likely require a large number of comparatively 'lower level' and easier to find set of skills and knowledge. However, a centralised plant would require a small number of comparatively high level technical skills to run the larger plant. This is particularly the case for the nuclear generation of electricity. As the UK has not introduced new nuclear generation since Sizewell b in 1995, development of new nuclear power may require importing the skills from overseas. However, it is likely that in the move to a decentralised electricity system the skills for a nuclear generating plant would still be required for the decommissioning of the existing generation plant. Although the skills to run a plant may be different from those required to decommission they would be of similar technical complexity.

Chapter eight looks at the changes to investment structure dictated by adopting decentralised electricity. In order for a secure low carbon future to be reality there is likely to be a large investment into the electricity system. This chapter discusses the investment profile for a low carbon, decentralised electricity system. Investments will be needed in the transmission and distribution networks as well as the generation capacity. There is a discussion of the investment into capacity, transitional fuels such as natural gas and how the markets and investors might respond.

Changing from a centralised to decentralised electricity system will likely change the number, relationship and power of the electricity sector stakeholders. Chapter nine discusses these changes looking specifically at the role of Government, Ofgem, Network Operators, System Operator and the Big Six energy companies.

Chapter 10 examines the role of the consumer in making the future electricity system secure and how this may change in a system of decentralised electricity generation. It looks at the use of demand management mechanisms and technologies, how to manage the complexity of the electricity networks and the impact of engaging a larger number of consumers which is the likely result of a decentralised electricity system.

2 The UK electricity system post 1990

This chapter looks at the changes to the energy system over the last few decades and how it has developed. It will discuss the Government's move away from directly owning assets associated with the energy industry and from control of the energy system. It also introduces the electricity market arrangements and provides an introduction to the more complex policies, mechanisms and institutions which will be discussed later in the thesis. In addition, it will identify the main stakeholders who operate at present within the electricity system and describe their various responsibilities and how they play a role in policy formation.

2.1 Privatisation and its impacts

The structure of the electricity system has changed dramatically since privatisation. The infrastructure, players, policies and the operation of the system have had to adapt to a range of factors from economics to the availability of natural resources and the requirements placed on electricity by consumers (Simmonds, 2002). Arguably one of the biggest changes to the electricity system was the privatisation of industry assets during the 1990s (Surrey, 1996). It was essentially a shift from public to private ownership in a bid for economic efficiency (Beder, 2005). The multifaceted nature of the system required new organisations to be set up, making the energy system the most complex privatisation the Government had hitherto undertaken (Green, 1991; Branston, 2002; Helm, 2003).

The privatisation of the electricity industry unlocked assets such as the electricity supply industry, transmission and distribution networks of the Central Electricity Generating Board (CEGB), valued at £32bn (Helm, 2003).

In addition, trade unions had recently exercised their power to severely disrupt the energy system, as shown by the 1981 miners' strike, making the Government appear as if they had limited control over the industry (PMSU, 2001). By privatising the energy system the strength of the unions was reduced as workers were transferred to the private sector. Privatisation also provided a wider share of ownership in the energy sector (Pollit, 2012).

Increasing the efficiency of the industry was another aim for the Government's move to a privately owned system (Thomas, 1996a; Pettinger, 2011). A state run power plant could be criticised for inefficiencies and therefore wastages. In theory, privately owned energy companies have an incentive to cut costs as a means to ensure profitability whilst in a nationalised industry, managers do not share any profits and therefore may have a reduced motivation to increase efficiency. State owned industry might also be considered inefficient because the priorities of the elected politicians managing the industry is often different to that of business managers (Moore, 1992).

From 1948 to 1990, the Central Electricity Generating Board (CEGB) owned the electricity supply industry and the transmission system as a monopoly, with twelve Regional Boards responsible for distribution and supply across England and Wales and a further two in Scotland (Newbery and Pollit, 1997).

The restructuring of the CEGB in the run up to privatisation saw the creation of four successor companies in England, two generating companies – National Power and PowerGen - Nuclear Electric, which initially held the nuclear generation, and transmission assets were transferred into the National Grid Company. In addition, the CEGB's twelve regional area boards were directly replaced by Regional Electricity Companies (REC), which owned and operated the distribution networks as well as supplying consumers (Domah and Pollitt, 2000). Initially, the RECs also owned National Grid, but had largely disposed of these assets by the mid 1990s (Help, 2003).

The Scottish electricity system was privatised at the same time as England and Wales. Scotland's two main energy companies: the South of Scotland Electricity Board (SSEB) and The Hydro Electric Board were replaced by Scottish Power and Scottish Hydro-Electric[2] respectively (Thomas, 1996a; Simmonds, 2002).

The privatisation of the Scottish electricity system was not followed with significant liberalisation. Vertical integration of the two Scottish companies was maintained leaving limited levels of competition and opportunity for new entry (Prandini, 2007). This dominance of the Scottish system by two electricity companies was not changed until the New Electricity Trading Arrangements (NETA) were extended to include Scotland under the British Electricity Trading and Transmission Arrangements (BETTA) (Green, 2010).

2 Hydro-Electric later merged with Southern Electric to form Scottish and Southern Electric (Simmonds, 2002).

2.1.1 'Dash for Gas' Electricity from gas fuelled electric plants

The introduction of competition and regulation of the electricity system provided a drive for greater efficiency in the sector (IEA, 2005; Pollitt, 2007). The reduction in the costs of gas turbines, the increased availability of gas as a fuel, coupled with the ability of new actors (often the RECs) to enter the electricity generation market meant that Combined Cycle Gas Turbines began displace coal fired generation. By 1996 gas had taken a 23% share in the electricity generation as can be seen in Figure 2-1 and Figure 2-2 (Newbery and Pollitt, 1997; DECC, 2009c). Replacing the 'dirty' coal generation with natural gas provided an additional benefit to the future electricity system in terms of an overall reduction in carbon emissions.

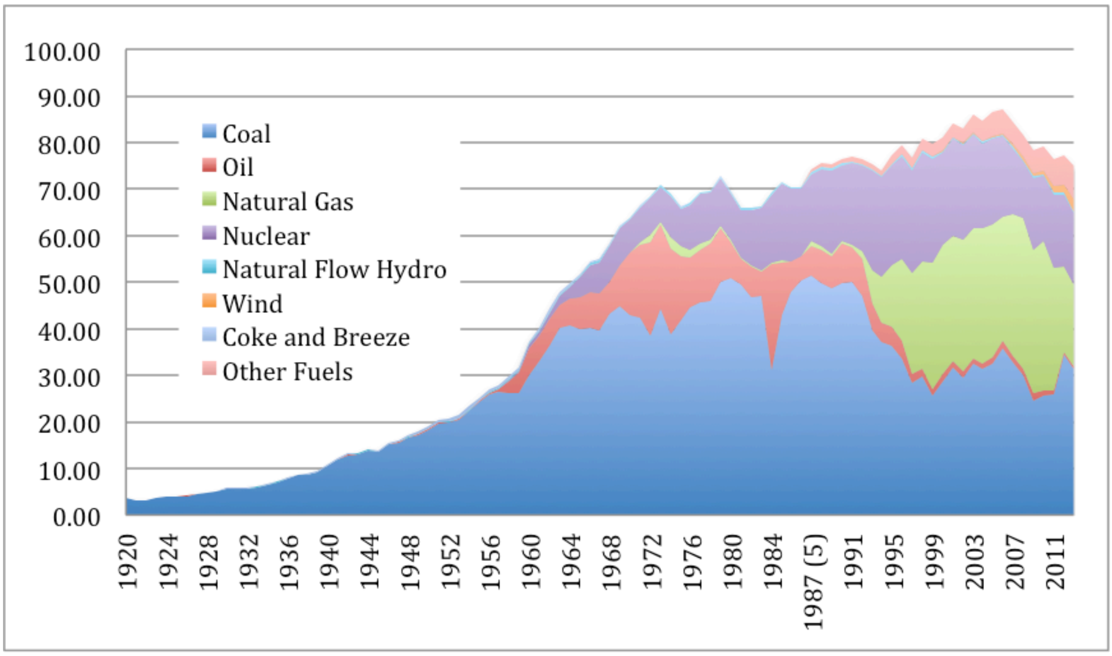

Figure 2-1 Fuels used to generate electricity 1948 to 2011 (DECC, 2013o)

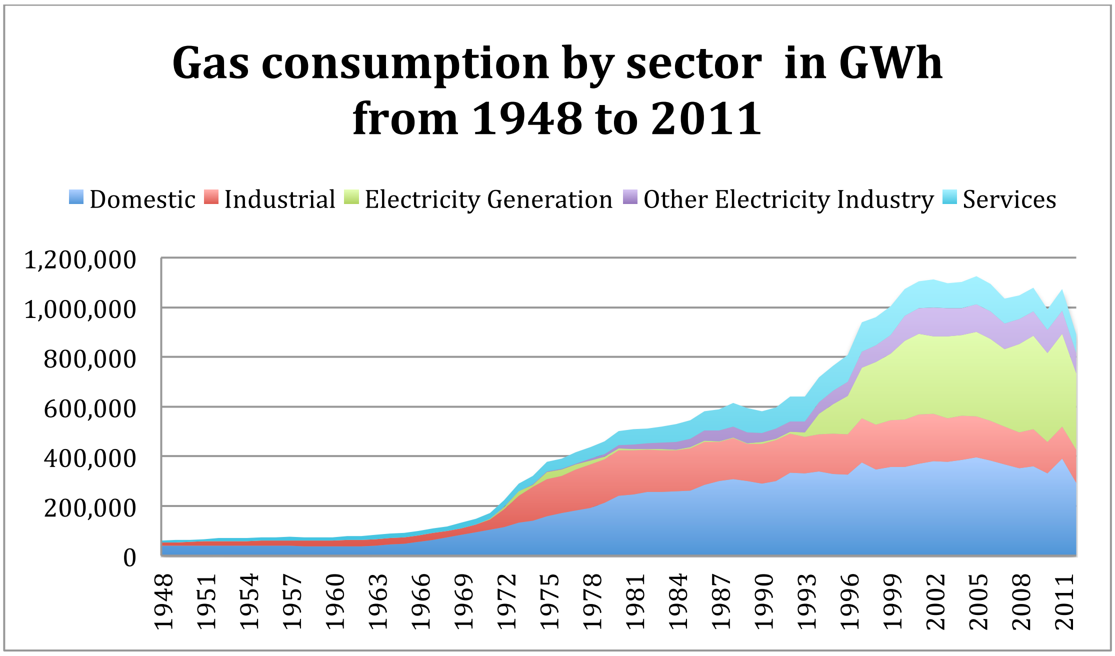

Figure 2-2 Gas consumption by sector (DECC, 2013b)

2.1.2 Retail Market Choice

The restructuring of the electricity industry was also intended to allow consumers to choose which supplier to use rather than depending on their local REC. This was opened up in three stages: the first tier market was opened up for customers with peak loads over 1MW (approximately 5000 customers). The second tier arrived in 1994 for customers over 100kW (allowing another 50,000 customers to choose supplier) and by 1998 the whole electricity market was open to competition introducing all 26 million domestic consumers to the market (IEA, 2002a; Thomas, 2002). The inclusion of choice for the consumers meant that the supply companies began competing for the consumers' custom. For example, by providing cheaper tariffs or other characteristics reflecting consumer preferences, in particular they were able to choose the source of generation (Helm, 2003).

2.1.3 The Pool

Following privatisation wholesale electricity was traded through 'The Pool' (see Figure 2-3). The Pool was set up to facilitate competition through a bidding process for generators setting the price of electricity on a half hourly basis (Lowrey, 1999). The generators were required to provide the price at which they were prepared to operate for the day-ahead and The National Grid Company would estimate the demand as a result of notification of demand and by determine the level of generation needed (Simmons, 2002). This meant that the cheapest technologies were operated throughout the day. The advantage of the Pool was originally stated as its transparency. The regulator could see the prices set by the pool and any abuse would be obvious (Helm, 2003).

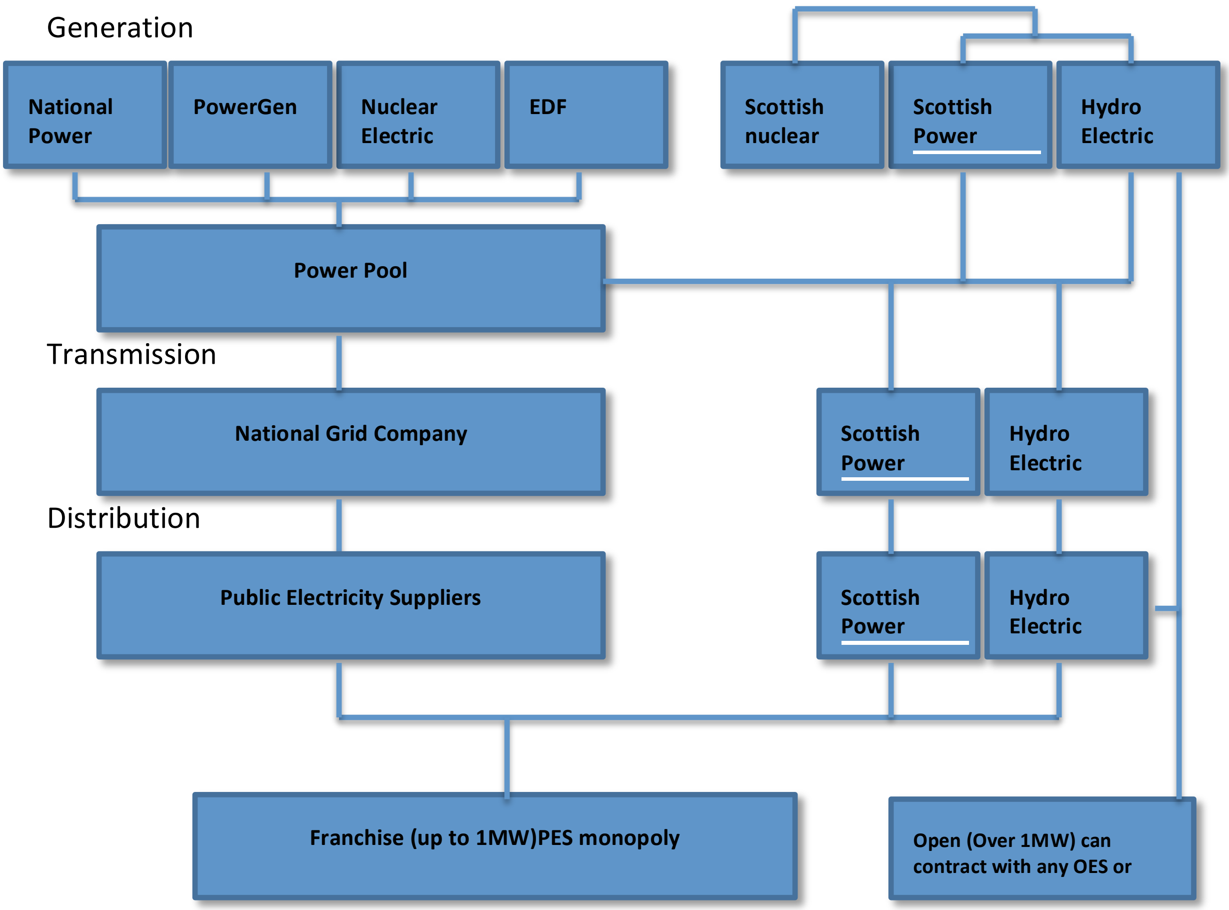

Figure 2-3 Structure of electricity industry at privatisation (Energy Review, 1999; Simmons, 2002)

In practice, half hourly prices in the England and Wales Pool, tended to be volatile because of their being only two trading companies. (Green, 1999). Alternative trading arrangements, known as Contracts for Difference (CfDs) emerged to provide more stable pricing: participants agreed a price for a fixed quantity of electricity and if the Pool price was lower, then the buyer paid the difference and if it was higher, then the seller paid (Green, 1999). Ultimately 70 to 90% of electricity was traded through CfDs (Thomas, 1996b; Green, 1999; Helm and Powell, 1992 in Helm, 2003).

2.1.4 NETA and BETTA

By the late 1990s it was increasingly obvious that the Pool was not achieving what it set out to do. The Pool prices tended to be volatile and therefore the bulk of the electricity was sold through bilateral contracts called the CfDs (Simmons, 2002). The use of the CfDs with the Pool meant there was limited transparency for the Regulator and resulted in the increases in efficiency made by the generators not being reflected in the reduction in price for the consumer (Ofgem, 2000). In addition, there were episodes of market abuse from National Power and PowerGen which resulted in inflated Pool prices and ultimately resulted in the Government requiring the two companies to divest some of their stations to reduce their market power (Newbery 1998).

The Labour Party came into power in 1997. Their view was that privatisation and the regulation of the electricity supply industry in 1990 had not been orientated enough to consumers. The Government implemented the Utilities act 2000 which established new duties for Ofgem and the creation of new market arrangements - the New Electricity Trading Arrangements (NETA).

NETA came into being in March 2001. It abolished the Pool and instead established a system of bilateral contracts for power between generators, suppliers, traders and consumers, with electricity traded at a price agreed by the counter-parties (ELEXON, 2011a). The use of bilateral contracts means the generators can self-dispatch to the network. However, they are required to notify the balancing mechanism of any differences to their contracts. The wholesale market works in three voluntary stages: forward and future contracts, short-term bilateral market and the balancing mechanism, as seen in Figure 2-4. The key characteristics of NETA are:

- Future contracts are made from up to a year in advance to 24 hours ahead of real time. These contracts are intended to reflect the majority of the trading between a supplier and generator.
- The short-term bilateral market, often called power exchanges is a way of sellers and buyers fine tuning their position as their demand forecasts become more accurate. These contracts can be made up to hour before real time.
- The balancing mechanism is operated by the System Operator arm of National Grid Company. It is designed to ensure that the supply and demand can be continuously matched.

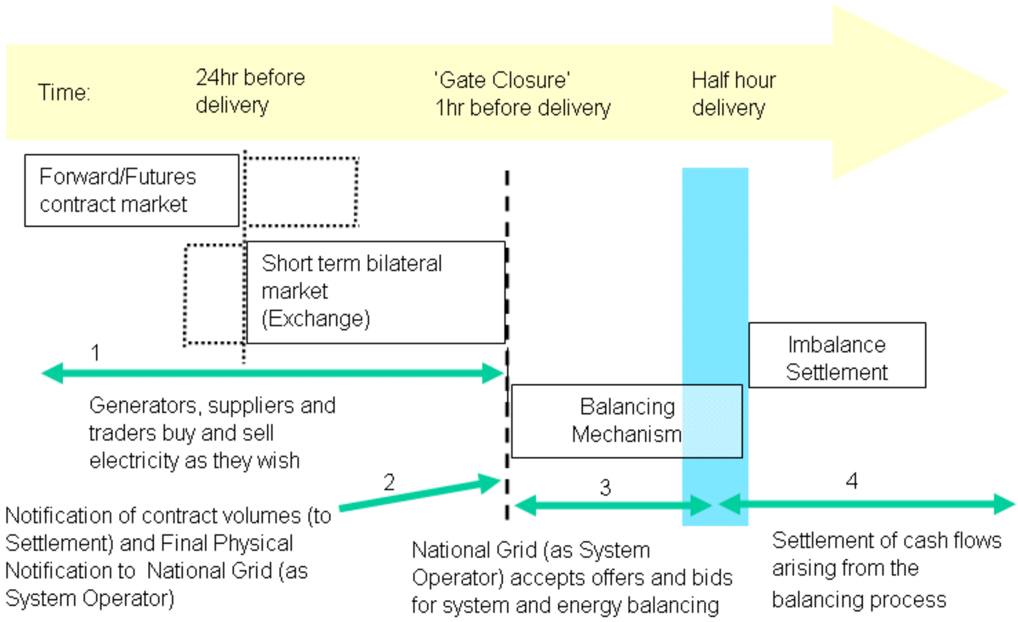

Figure 2-4 New Electricity Trading Arrangements/British Electricity Trading Arrangements (National Grid, 2011b)

The deadline, known as Gate Closure, for agreeing bilateral contracts or trading is one hour before delivery. At Gate Closure, market participants are expected to adhere to the volumes of output or demand they have contracted for, and any residual imbalances on the system, whether on the supply or demand side, are corrected by the System Operator. The System Operator seeks out the lowest offers and the highest bids, whilst taking into account the transmission constraints which are necessary to balance the system (ELEXON, 2011a). The power flows are metered in real time in order to determine the imbalance between the participants' contractual position and the physical flow. The imbalance volumes are settled using the system buy price (SBP) and the system sell price (SSP). This means that the System Operator when faced with a deficit of electricity will take the next cheapest bid – but this will always be higher that the marginal price of the market and may be very high. A similar system acts in reverse for a lack of demand (National Grid, 2011).

In addition to this there is a mandatory post-event settlement process, which is organised by the Balancing and Settlement Code (BSC), administered by System Operator. Parties which have been out of balance from their stated position at Gate Closure (either on the supply or the demand side) are charged a penalty by the System Operator as a reflection of the costs incurred by it to keep the system in balance.

In 2005 the trading arrangements were extended to cover Scotland and Wales and became the British Electricity Trading Transmission Arrangements and created a single electricity market for the UK. While transmission networks in Scotland are still owned by the two Scottish companies, the operation of the overall British electricity transmission network has been taken over by the System Operator function of National Grid.

These electricity arrangements were designed for output from large scale, predictable, continuous and inflexible generation such as fossil fuels and nuclear generating stations (House of Commons Energy and Climate Change Committee, 2011). However, the expected increase in deployment of renewable technologies results in there likely being an increase in the levels of variable generation[3] technologies where the output may be more difficult to predict on a day to day basis. Investment in a variable source of electricity generation which actively participates in the current market system, can be considered risky, because over- or under- generation from the stated position before gate closure will result in penalties from the Balancing Mechanism (Baker et al., 2010). Therefore, the variable buyers and sellers need other markets to hedge their investment and reduce risk.

3 Not all renewable generation is variable. Wind and solar power can come under this category, however marine and biomass can be considered predictable.

2.1.5 Purchase Power Agreements

The risks of being exposed to penalty payments in the balancing mechanism means that small-scale independent generators are unlikely to participate directly in trading in the market. This is exacerbated by the complexity of operating in a 24 hour market-based on a complex set of legal and industry codes. The transaction costs associated with BETTA are prohibitive for small-scale participants (as opposed to renewable projects owned by the Big Six incumbent energy companies). Instead, small-scale generators tend to access the market through Purchase Power Agreements (PPAs). A PPA is a contract set up between a generator and a supplier. It often includes an imbalance risk premium (meaning the generators are paid less than the value of their electricity were they able to sell directly) as a way of compensating for the variability of generation, ultimately reducing the overall price received for their output (Hesmondhalgh et al., 2010).

2.2 Electricity Market Reform

The changes expected to the future electricity system discussed in chapter 2 will require a change to the operation of the market. The Electricity Market Reform (EMR) of 2010 – 2014 is intended to establish mechanisms to replace and upgrade the UK's infrastructure by incentivising a further £110bn worth of investment (DECC, 2012n). This reform has two main features: the Contracts for Difference (CfD) and the Capacity Mechanism (CM) and two secondary features: the emissions performance standard and the carbon floor price already functioning under the finance Act 2012.

2.2.1 Contracts for Difference (CfDs)

The Contracts for difference (CFD) are essentially a support mechanism for low carbon electricity generation, designed to replace the renewables obligation (RO) for renewables and include nuclear and carbon capture and storage (CCS) generation. The contracts are held between the generator and the Low Carbon Contracts Company[4] and provide a fixed price for the sale of the electricity generated. The Government states that new investors should be able to utilise the new CfDs, allowing more investors into the system, which it is hoped will boost competition within the market (DECC, 2014c).

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4 A private company, owned by the Department of Energy and Climate Change (DECC), The CfDs operate by setting a fixed 'strike price' which is set in advance of the contract and a reference price which moves in relation to the wholesale price of electricity. The generator 'topped up' from the reference price to meet the strike price and if the reference price exceeds the strike price the generator is required to pay the difference back (see Figure 2-5).

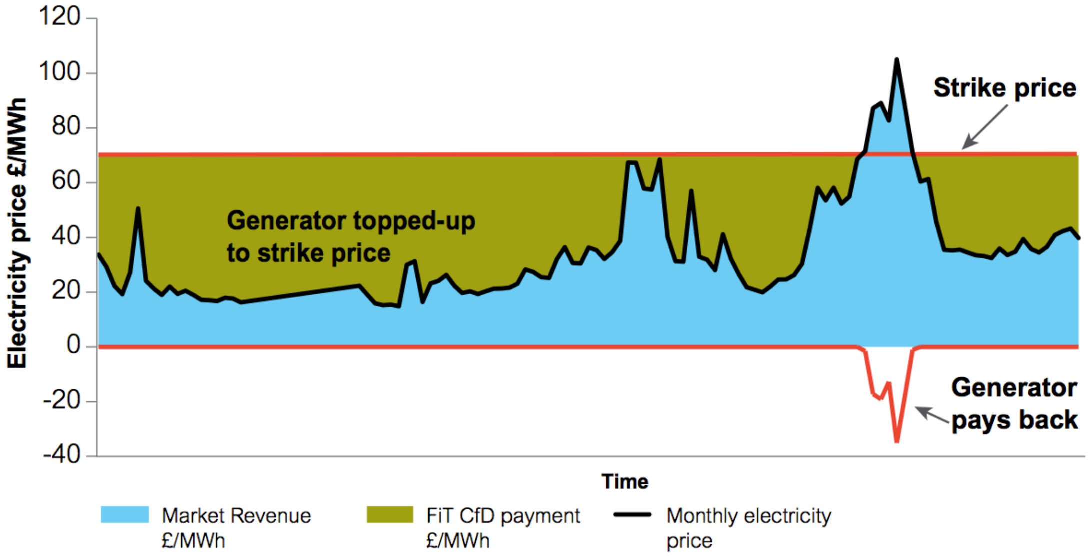

Figure 2-5 The operation of an intermittent Contract for Difference (DECC, 2011a).

However, the contracts for difference have been criticised for many reasons, such as, their complexity and increased costs for consumers (Toke, 2013). Although the CfDs operate for renewable technologies, nuclear and CCS, the operation will be differ for the variable renewable technologies. Firstly with the length of the contract, the renewable generation contracts would last 15 years whereas nuclear could be for 35 years (Jowit, 2013). Secondly, for renewables the reference price will track the market price by the day ahead market, meaning the reference price will move closely with the wholesale market price. For nuclear the reference price will be set for 12 months looking at the average year ahead wholesale price. Thirdly, the strike price will be set differently. For variable renewable generation the strike price will be imposed upon them. However, nuclear generation will be able to negotiate its price for each generation station. This is why the CFDs have been criticised as a way for Government to subsidise the nuclear industry without clearly identifying the amount of subsidy in comparison to the renewable generators (Toke, 2011). Further to this the Levy Control Framework (LCF) effectively caps the amount of money that can be spent on low carbon generation. The LCF has set out money until 2020 but it is not known how much there will be after 2020. Once nuclear power comes on stream then it is not clear how much money will be left for promoting renewables. Any subsidy of the nuclear industry would likely mean less money for renewables.

2.2.2 Capacity Market

A key aspect of the UK Governments Electricity market reform package is the implementation of a capacity market (CM). The Government's aim for the CM is to stimulate sufficient investment into electricity generation capacity to meet electricity demand at all times. The capacity providers will be offered a fixed payment to ensure capacity and penalised for failing to deliver that capacity (DECC, 2012e, DECC, 2014a).

The capacity market consist of six stages: firstly, the amount of capacity to be auctioned is decided by the Minister of Sate (DECC). Secondly, eligible applicants[5] participate in a pre-qualification process run by the delivery body (The National Grid, System Operator). The third stage is the auction, where successful pre-qualification applicants compete for capacity agreements four years ahead of delivery the first of which will be for 53.3 GW in December 2014 (DECC, 2014d). The fourth stage is the secondary market, where participants can trade (financial or physical) agreements between the auction and delivery. The fifth stage is the delivery, where payment is provided for the capacity and penalties for non-delivery of their agreement. Finally, the payment for the participants, which is run through a settlement company (DECC 2013h).

One of the main positive aspects to take from the capacity mechanism is that it has identified the use of demand side response in the securing of the electricity system. It signifies the move away from supply meeting demand at any cost (Thorpe, 2013), although demand side response is still a very small aspect of the mechanism (Mitchell, 2014a).

The future of the electricity system may see an increase in the level of electricity demand if the electrification of heat and transport develops and energy efficiency schemes are not sufficiently widespread enough to meet this increase. In addition

5 Eligible applicants includes generating capacity, demand side response and storage which is not supported by the RO, CfDs, FIT or RHI. It also does not include non-GB generation from the interconnector.

an increase in low carbon renewable generation will mean supply will have more variability. If this is the case, then in order for supply to meet demand there has to be an increase in capacity. One solution is for Government to operate peaking plant itself, thereby ensuing sufficient capacity at times of peak demand (FoE, 2012). However, this would mean that Government would be responsible for the short-term supply and not only taking on the risk of supply meeting demand would also be taking on the political risk if anything supply standards were not met.

However, the CM has been criticised for promoting older, coal fired power stations. The long-term, guaranteed contracts for these coal power plants would mean they would be able to calculate the cost of upgrading the station in order to meet the EU directives. These directives will come into place in order to force improved environmental performance (Littlecott, 2014). However, since then the long term contracts for older coal fired Power stations have been removed (Carrington, 2014).

2.3 Network Regulation

Electricity transmission and distribution networks operate as monopolies and are regulated by Ofgem to ensure electricity and gas is delivered in an affordable and reliable manner. Ofgem have estimated that the transmission and distribution networks will need to invest over £30bn (gas and electricity) over the next decade (Ofgem, 2012g). Currently around 20% of the consumer electricity tariff is related to the distribution and transmission network charges (see Figure 2-6) meaning the cost of upgrading and maintaining the networks are central to the future of the system, especially if this future requires changes to their operation (Ofgem, 2013a). In order to meet the challenges of the future, a secure delivery system for electricity is needed. This will have to cope with the additional usage from potential increased demand (Government has identified that the future will include the electrification of heat and transport (DECC, 2012n)) and reduced predictability from variable generation sources (Pollit and Bialek, 2007). However, it should be noted that some of this investment would be required irrespective of any other changes in order to replace aged part of the network. The key is to ensure that this infrastructure investment allows further development of the network to provide energy security and a low carbon future for electricity generation.

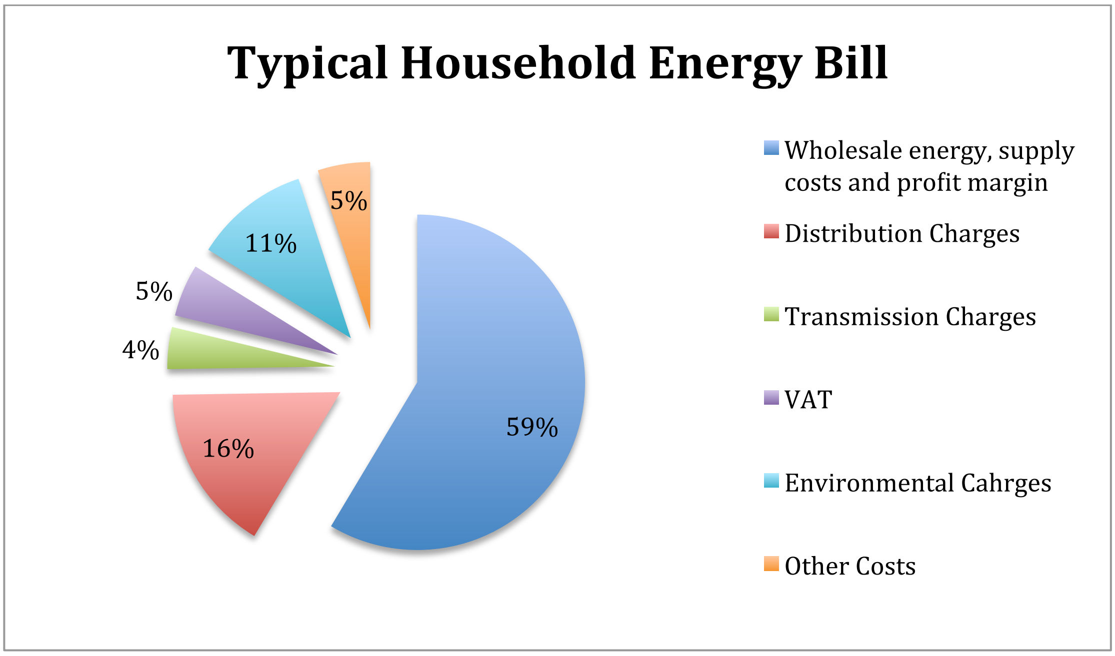

Figure 2-6 Typical Household Energy Bill based on average annual consumption figures of 3,300 kWh for electricity across all big six suppliers and across Great Britain (Ofgem, 2013a)

Ofgem regulates distribution through the networks by the price controls which set the DNOs' revenue allowances at a fixed sum[6] over a five-year period. These were designed to set a 'fair' return of capital after running costs and at the moment is structured over a five year period. The current price control runs from 1 April 2010 to 31 March 2015. This will change to RIIO and eight year periods after 2015, see section 2.3.1 for further explanation.

The network companies recover their allowed revenues from the supplier companies which in turn pass them on to the consumer. The current price control period set these returns through a mechanism known as RPI-X, where RPI is the Retail Price Index reflecting the rate of inflation, and X is a factor by which returns are reduced from this level in order to drive efficiency gains[7] (Crouch, 2006; Shaw et al., 2010; Ofgem, 2010g).

Initially the RPI-X approach was successful in its aim to improve the economic and operational efficiency of the DNOs. The regulation of the networks achieved a 55% reduction in the price of electricity distribution from 1995 to 2003 and 30% reduction in transmission costs from 1993 to 2005 (Pollit, 2005). However, the

6 Revenue allowances have some variables such as changes to activity and inflation (Ofgem, 2009)
7 The X factor could also be positive rather than negative, in order to reflect increased investment or risk.

emphasis on efficiency improvements within the DNOs led to 'asset sweating' and a degree of under-investment as the companies sought to maximise their revenues (Helm 2003). This in turn created a concern about ageing networks which would be unable to cope with future shifts in patterns of demand and increased levels of decentralised generation connecting to them.

In addition to the day to day financial regulation of distribution networks, Ofgem also set up and administered a number of mechanisms intended to promote network innovation. These included the Innovation Funding Incentive, Distributed Generation Incentive and the Registered Power Zones each of which commenced in 2005 (Ofgem, 2005; SP Power Systems, 2005; Ofgem, 2007b). They were devised as a response to the perceived underinvestment in distribution networks, and the resulting difficulties for connection of generation to the networks.

As a part of the price control running until 2015 the Low Carbon Network Fund is allowing up to £500m to support projects sponsored by the Distribution Network Operators. This funding is broken into two different tiers, each of which focus on the distribution network. Tier 1 with £80m of investment covers the small-scale projects which include the trialling of new equipment, new arrangement of existing equipment. Tier 2 provides £64m worth of funding per year and includes a competitive bidding process. The projects to be funded are decided by Ofgem, who require that they development and demonstration of new technologies including novel operating and commercial arrangements (Grünewald et al., 2012; Ofgem, 2013e). However this is, which is to be replaced by the Network Innovation Competition (NIC) set out by RIIO.

2.3.1 RIIO (Revenue = Incentives + Innovation + Outputs)

The energy networks are in a period of change, in 2010 Ofgem began the review of energy network regulation RPI-X@20. RPI-X@20 signified the need for a new regulatory framework which according to Ofgem will need to secure enough investment to maintain a reliable and secure network, and dealing with the changes in demand and generation that will occur in a low carbon future.

Revenue = Incentives + Innovation + Outputs (RIIO) is the new regulatory framework designed to cover the energy networks from gas to electricity transmission and distribution. The main ethos behind RIIO is to set up a regulatory system where outputs were rewarded and companies delivered what customers wanted in an efficient manner. There are four main objectives for RIIO: firstly, to put stakeholders at the heart of their decision making process. Secondly, to invest efficiently to ensuring continued safe and reliable services. Thirdly, promote innovation to reduce network costs for current and future consumers. Finally, play a full role in delivering a low carbon economy and wider environmental objectives (EC Harris, 2013)

The distribution and transmission network companies are given predefined objectives. How they perform against these objectives will determine their rates of return and the level of scrutiny of future regulatory reviews. (Bolton and Hawkes 2013). Companies submit business plans on how they intend to meet RIIO framework. Ofgem then reviews these plans to determine levels of scrutiny, which will be applied, i.e. a good business plan can be fast tracked, a bad one will be re-submitted. The first set of business plans for the distribution network companies were issued in November 2013, five out of the six companies plans were rejected as they "did not sufficiently demonstrate value for money" (Ofgem, 2013j).

The main aspects of the RIIO which change from the current regulatory framework are: firstly, the longer price control period (eight years from five), secondly, an emphasis on innovation through funding competitions, thirdly, output-based regulation, fourthly, fast tracking (an early start to operations networks if business plans line up fully with Ofgem's view) and finally, an emphasis on customer service (EC Harris, 2013).

The price controls are in three parts: firstly for the transmission system (TIIO-T1) which covers the transmission of gas and electricity, for the period of 2013 to 2021 and accounts for 2% and 4% of the consumers bill for gas and electricity respectively. Ofgem's decision on National Grid's price control package was published in December 2012. These proposals earmark around £15.5 billion of investment to upgrade and renew the networks over the course of the price control. The second is the electricity distribution (RIIO-ED1) for the distribution network owners covering the period of 2015 to 2023 which accounts for 16% of the consumers bill. Finally there is the gas distribution price control (RIIO-GD1).

RIIO includes an innovation stimulus package for the networks, including the Network Innovation Competition (NIC) which replaces the Low Carbon Network Fund (LCNF) for transmission and distribution networks. The NIC is an annual competition for companies to compete for a total of £27m. The competition is focused around innovation projects which provide the best environmental benefits, cost reductions and security of supply. Another innovation mechanism is the Network Innovation Allowance (NIA) which in general will fund small-scale projects by allowing 0.5% of the companies revenues to be spent on small projects. Some projects being allowed up to 1% of revenue. These are for smaller technical, commercial or operational initiatives that have the potential to deliver financial benefits to the licensee and its customers or as a prototype for the NIC.

As RIIO is still in its infancy in terms of its operation so the impact it will have of the electricity system is still unclear. The new innovation schemes have the potential to promote network development and the greater inclusion of customer value for money has the ability to benefit affordability. However, previous network innovation mechanisms have proven unsuccessful for two main reasons. Firstly the lack of emphasis on the development of new innovation, secondly the DNOs placed a low priority on network innovation and therefore there was a low uptake (Woodman and Baker, 2008).

The main challenge for the future of the distribution system is that they will have to incorporate an increase in locally distributed generation on their electricity networks. The short-term issue with increased generation is that constraints on the network can mean a network will need upgrading in that area before the generation is connected. With the RPI-X system (and which seems to be the same with RIIO) these upgrades are made when the need arises. What is required is an investment model where the networks operators upgrade the network within a region, making their networks more efficient rather than reacting to pressure from the generators. If this investment model existed small-scale generator might find that a barrier to investment is removed.

The future of the electricity system could see a large amount of decentralised electricity generation on the distribution network, which would dominate the GB electricity portfolio. In order for this to happen the electricity networks will need to change dramatically, firstly, in order to be able to receive the generation, secondly, to manage the flow of electricity. The management will require new operational procedures and technologies which could see electricity flowing from the distribution networks to the transmission networks. The regulatory system that was developed during a period of highly centralised electricity generation and delivery. RIIO goes some way to promoting innovation further but not at the level required in order to meet a decentralised electricity system.

2.4 UK Government goals and policy

As overarching drivers for the energy system the Government has established three objectives for energy policy: to *"decarbonise energy generation"* (climate change), to "*keep energy bills affordable"* (affordability) and to *"keep the lights on"* (energy security) see Figure 2-7 (DECC, 2012n: Pg. 7). These three goals have been the mainstay of the Government energy policy for the last decade. The wording may alter but the goals always include climate change, affordability, and security (DTI, 2003; 2007a; DECC, 2009a; 2012d, 2012n).

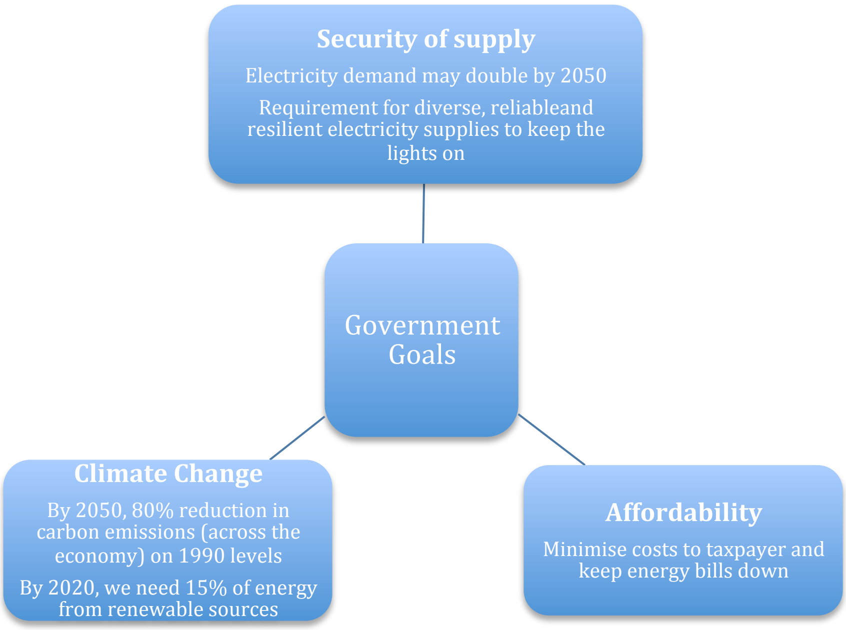

Figure 2-7 The Government's objectives for the electricity system (DECC, 2012n).

The three goals constitute a 'trilemma' in terms of trying to meet each challenge because each can conflict with the other (Sautter et al., 2009; Blumsack and Fernandez , 2012). There are links between policies, for example, reducing dependence on fossil fuels will reduce carbon emissions and potentially reduce the impact of global price spikes, helping both affordability and energy security goals. However, there are also trade-offs such as the closing of many of the power plants as a result of EU environmental policies could undermine the ability to produce sufficient capacity levels and impact on day-to-day security of supply (DECC, 2011a). The extent to which a government focuses on one or another, or all of these goals will have an impact on the development of the energy system. Nevertheless, the goals provide a useful way of classifying different policy actions, and the three areas are discussed below.

2.4.1 Climate Change

The UK Government has recognised the importance of climate change and the impact of carbon emissions on the environment i.e. the Energy White Papers (EWP) published in 2003, 2007 and 2012. They have committed the UK to reducing carbon emissions by 80% by 2050 from 1990 levels. This target for carbon reduction has been backed up by a requirement in law under the Climate Change Act (2008) to meet a set of carbon budgets up to 2050. The first four of these budgets have been set and cover the period of 2008 up to 2027 (DECC, 2009b & 2011i).

According to the Government, the UK is currently on target for meeting the first three of the carbon budgets (DECC, 2012L). However, the fourth budget, which entered into legislation separately in June 2011 represents a greater challenge than the linear projections of the first three as described in Figure 2-8, requiring a greater change to the system (Gambhir & Vallejo, 2011).

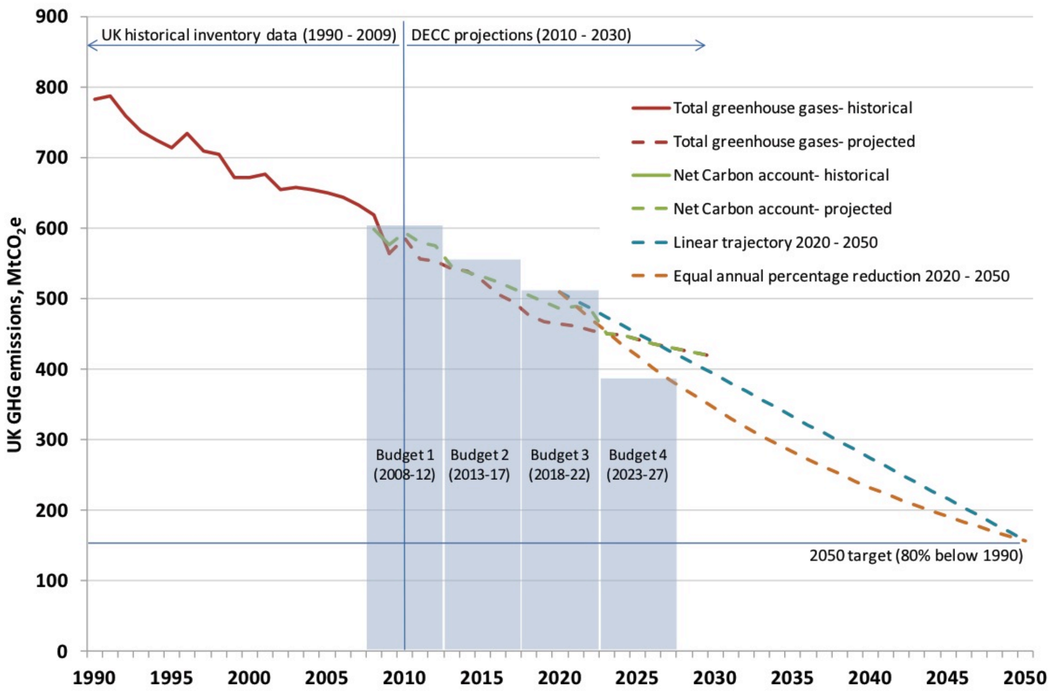

Figure 2-8 UK historical GHG emissions to 2009 and projections from 2010 (DECC, 2011h in Gambhir & Vallejo, 2011)

The energy supply sector provides the single biggest source of carbon emissions estimated at around 40% of the UK's total carbon emissions in 2011 (DECC, 2013a). So far the energy supply sector has been able to reduce its carbon emissions from 241.5 MtCO_2e in 1990 to 182.2 in 2011 which is a reduction of 24.5% (DECC, 2013). Reductions in carbon emissions, shown in Figure 2-9, for the electricity industry have been achieved through an increased use of gas over coal and the introduction of zero carbon technologies such as renewables (DECC, 2013a). This is indicated in Figure 2-10, showing the changes to fuel mix for electricity generation. However, many of the projections for demand can be contested, possible future changes to the electricity industry include the electrification of heat and transport which would increase the level of demand. Alternatively, an increase in the level of energy efficiency would lead to a reduction in demand levels and therefore, further cuts in emissions (DECC, 2012n; Energy and Climate Change Committee, 2012).

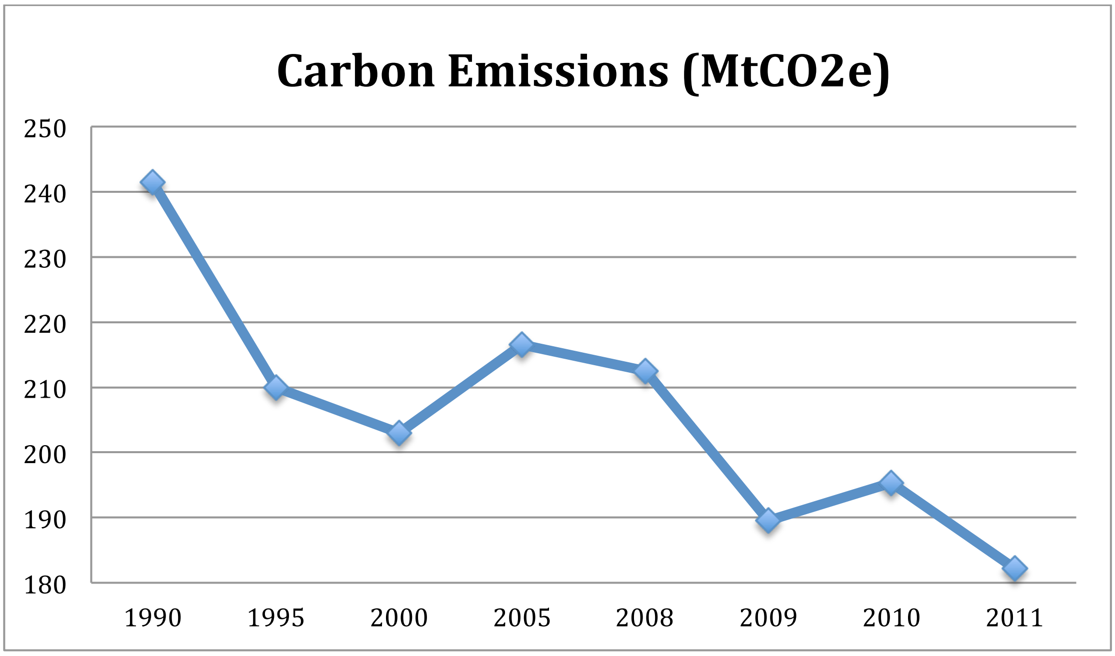

Figure 2-9 Energy supply sector carbon emissions, 1990-2011 (MtCO2e) (DECC, 2013a)

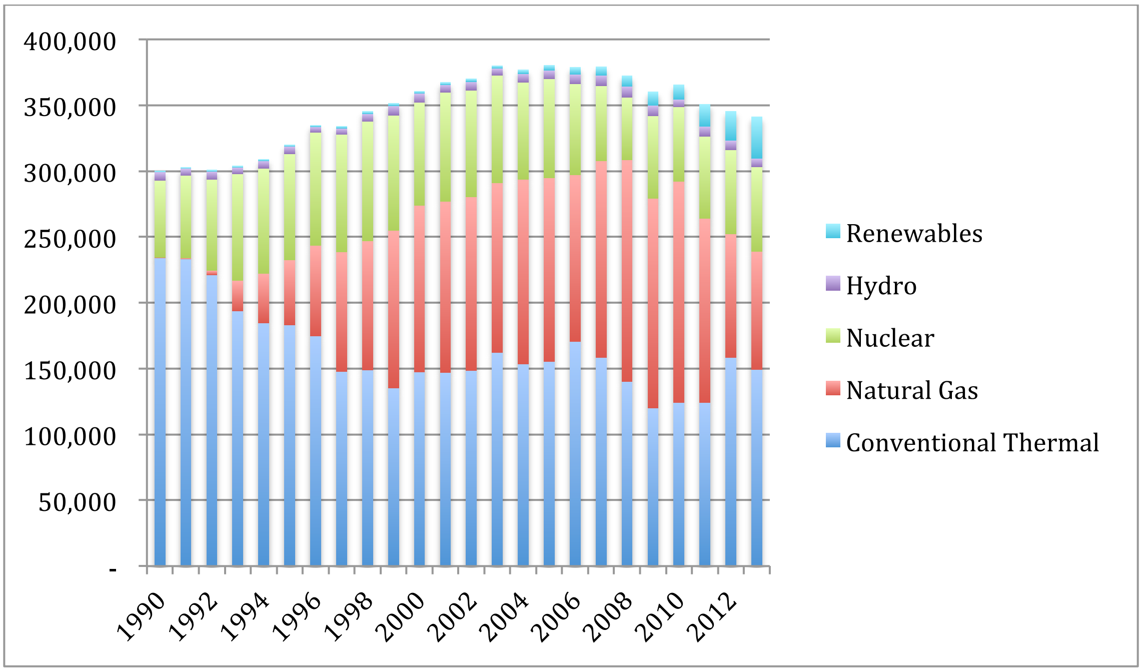

Figure 2-10 Fuel mix for UK electricity supplied, 1990-2013 (GWh) (DECC, 2014f)

2.4.2 Affordability

The policies designed to reduce the impact of climate change could have the impact of adding costs to the energy system (as a result of financing low-carbon investments and energy efficiency measures (Ofgem, 2010a; CCC, 2011; DECC, 2013d)). These policies may drive up average household energy bills by £240 per annum by 2020 (nPower, 2013). In 2012 the Committee on Climate Change (CCC) suggested that by 2020 the projected electricity bill will have increased by £100 as a result of subsidised CfDs in low carbon technologies. This added to the wholesale suppliers and networks increase in costs is likely to raise raises the bills by £185. The CCC identifies an £85 'potential' reduction in electricity costs from efficiency savings leaving a £100 total increase in costs from 2011 to 2020; with a similar increase in the costs of the average residential gas bill (an increase of £70) (CCC, 2012; 2013b). This is different to the DECC results of a 11% reduction in the total energy bill for household consumers (DECC, 2013d). In addition to this the term 'consumers' refers to a range of actors not simply householders.

However, the overall idea is that increasing energy efficiency of domestic households will mean that households will use less energy thereby offsetting the price rises with bills remaining the same or even reducing. Energy efficiency policies are therefore a key strategy for maintaining affordability. Nevertheless, affordability of energy to the consumer has become a political priority alongside climate change and energy security (Oxford Economics, 2011, DECC 2011k).

The Government has developed a range of strategies, which help householders and businesses use less energy, get the best deal on their energy tariff, and it provides payments for the most vulnerable. The rise in prices was described by Government as a short-term issue and that in the long run a more energy efficient system will lead to lower energy prices overall. However, these issues have become 'political' and dominated the media from mid 2013. (DECC, 2013d see Figure 2-11).

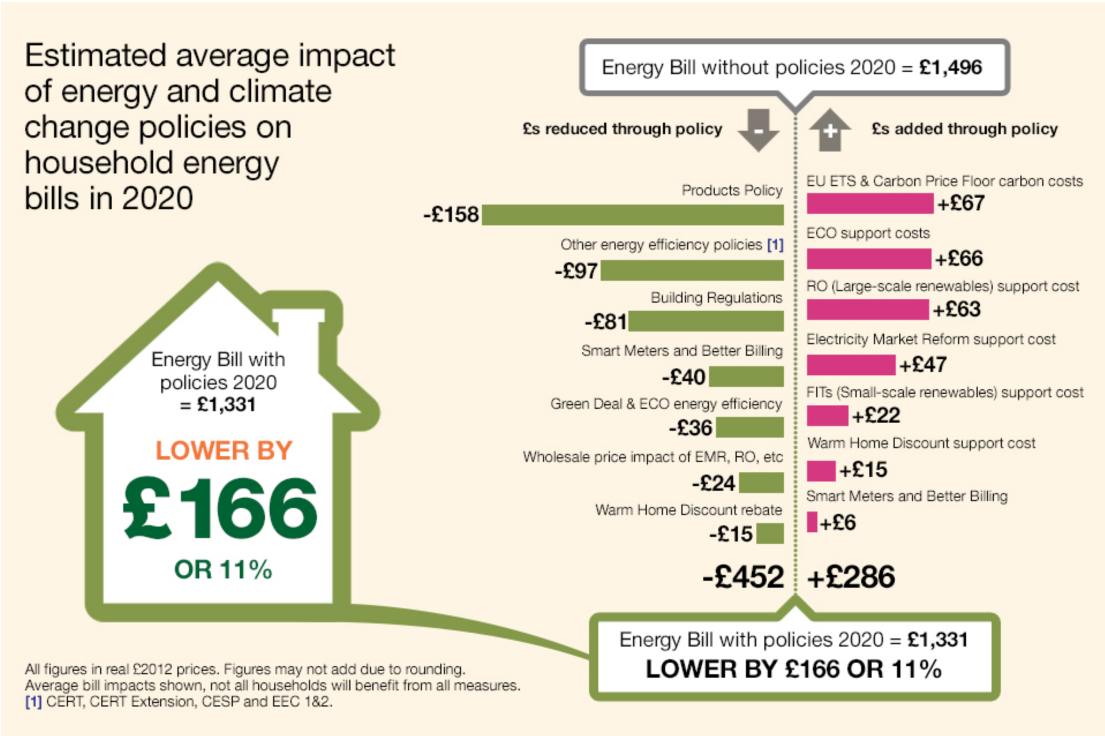

Figure 2-11 Estimated average impact of energy and climate change policies on household energy bills in 2020 (DECC, 2013d)

Key problems are to establish what the 'price' of electricity are how much profit the large energy companies are making (HoC ECCSC, 2013) and secondly how to establish what investment will be required in the coming decades to transform to a low carbon energy system.

Moreover, the impacts on consumers differ depending on what type of consumer they are. A rise in energy prices will mean reduced profitability in the short-term for energy intensive businesses and industry. However, this may not be the case in the longer term if rising prices stimulates them to invest in more efficient technology (Ockwell, 2008). The business sector is impacted upon differently by energy policies such as the CRC Energy Efficiency Scheme, and the EU ETS (DECC, 2011g). The impact of these policies to medium size businesses over the next two decades have been identified by the Government in Figure 2-12. However, it is important to note that the impact of these policy changes will depend both on the size of the business but also the success of the policies. This is factored into the Government's policy impact document by discussing medium and large businesses (DECC, 2011i). The future costs to commercial and industrial users are projected to increase faster than the householder because of these low carbon policies. It is estimated that costs of electricity will increase by up to 20-25% from 2013 to 2020 for commercial and industrial users. However, the cost of energy considered as a factor of the total costs to the sector, are low: between 0.5% and 3%. Therefore, the increase in energy costs may have little impact on the final cost of goods and services (CCC, 2012).

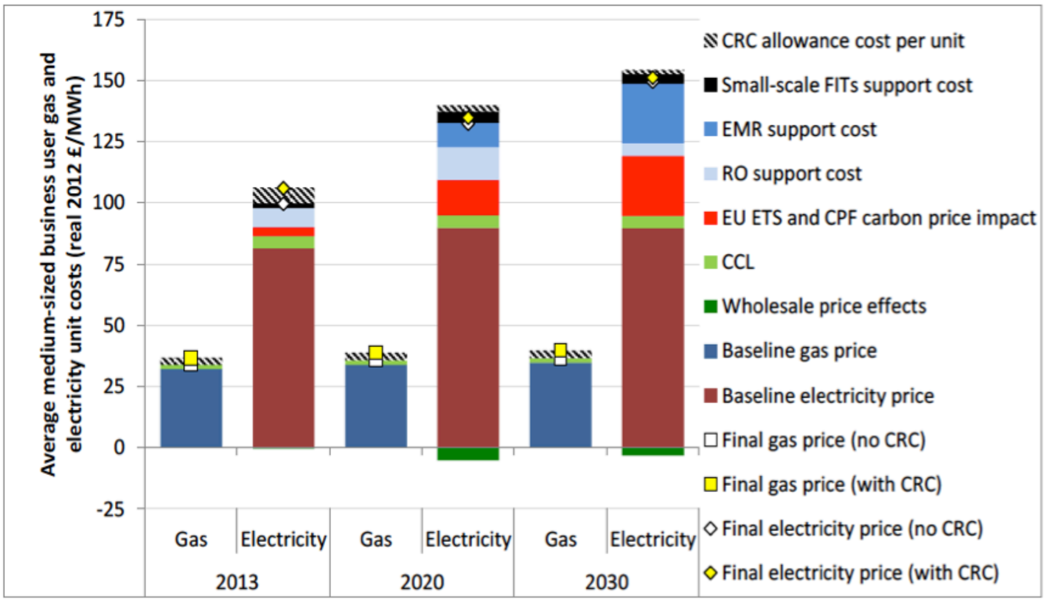

Figure 2-12 Estimated impact of energy and climate change policies on average retail gas and electricity prices paid by UK medium-sized business users (DECC, 2013m).

Domestic consumers have been the subject of specific policy action to limit the impact of fuel price rises and volatility on the levels of fuel poverty. In 2000, The Warm Homes and Energy Conservation Act placed a duty on Government to have a strategy for making sure no person lives in fuel poverty as far as is reasonably practical by 2016. However, in 2012 a report into fuel poverty commissioned by DECC was produced to examine three issues: firstly if fuel poverty was an issue, secondly; how it can be measured, and thirdly, the implications of measurement for policy approaches (Hills, 2012). The Warm Homes and Energy Conservation Act (2000) defined fuel poverty as: *"a member of a household living on a lower income in a home which cannot be kept warm at reasonable cost."*

The number of householders in England in fuel poverty has risen since 2004 see Figure 2-13. The drop in numbers for 2010 can be explained by a reduction in energy prices for that year, however, the price of energy for 2011 increased again by 5.5% and therefore a rise in fuel poverty is expected again (DECC, 2012m; 2012w)

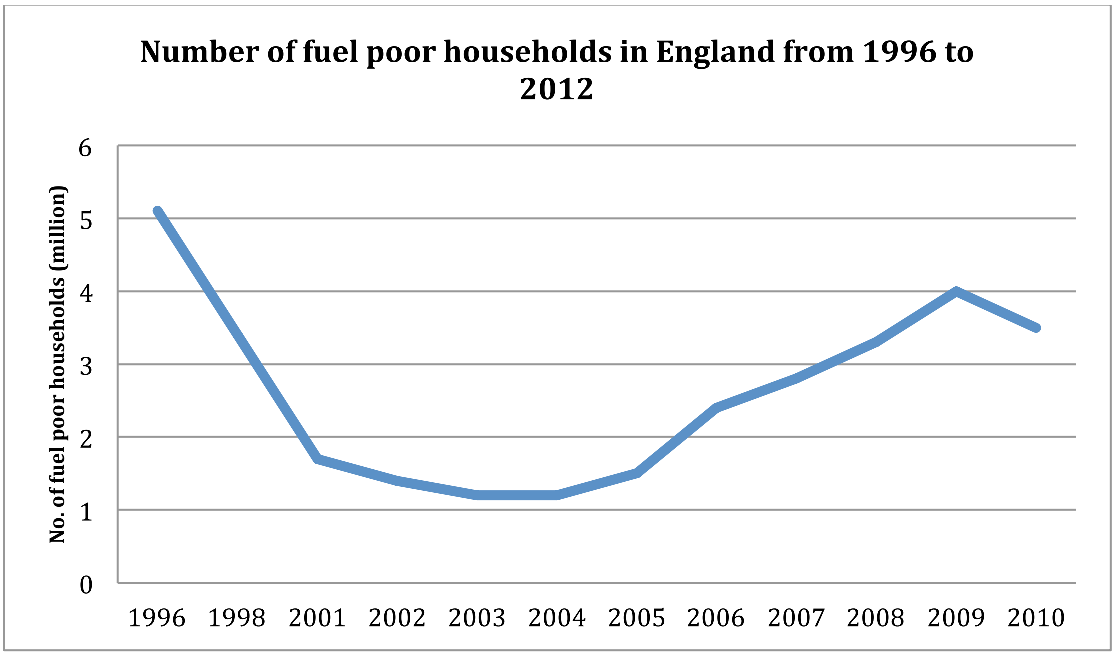

Figure 2-13 Number of fuel poor households in England (DECC, 2012m)

An issue with affordability is that if the price of energy increases for the household, as discussed by the CCC (CCC, 2012), then some of the strategies in place to protect the 'fuel poor' could increase the cost of energy to the rest of the consumers, thereby potentially increasing the numbers of fuel poor.

2.4.3 Energy Security

Energy security is a main aspect of this thesis and will be discussed in greater detail in chapter 4. Therefore, this section will be used to provide a précis of energy security from the Government perspective.

The UK Government currently describes energy security as *"making sure consumers can access the energy they need at prices that are not excessively volatile"* (DECC, 2012o). Although energy security has been a factor involved in many of the policy decisions and Government has recently published a strategy setting out key policies, it does still rely heavily on competitive markets as the means of maintaining security of supply (Parliamentary Office of Science and Technology, 2012).

However, energy security challenges are complex and range from local through to global and are continually changing (Mitchell et al., 2013). Energy security has to embrace issues such as the environment, governance patterns and international issues. It includes threats such as domestic activism; the balancing of supply and demand on electricity networks; and availability of resources. These threats could lead to blackout or brown out situations and are likely to cause the cost of electricity to rise. A secure, sustainable and affordable electricity system would need to be flexible and dynamic in order to combat these threats as well as provide protection for the fuel vulnerable. It should also provide a reliable supply of fuel and ensure that any policy or action to improve security does not undermine the economy. All of this has to exist in an energy industry which is decarbonising energy production; where domestic gas resources are depleting; and where the ageing fleet of power plants and networks causes uncertainty in the future pathway of the electricity industry. This understandably creates uncertainty for investors at a time when investment is greatly needed. Uncertainty is likely to lead to reduced investment again impacting on the ability of a system to provide secure energy.

Recent moves to reform the electricity market are designed specifically to meet this challenge by finding the low carbon investment required for the electricity system to replace the lost capacity and meet predicted increases in demand (DECC, 2012n). Energy security is currently seen as a challenge for Government, but not one that has been difficult to meet historically, however, issues are now changing. With so many changes to energy system on the horizon, ensuring the security of the system may become increasingly important.

2.5 UK Energy Targets

The UK Government has identified the need to reduce carbon emissions and reduce the energy system reliance on fossil fuels. As such it has implemented a set of targets, which are designed to tackle these issues. The main targets are, to reduce carbon emissions by 80% by 2050 from 1990 levels (Climate Change Act, 2008). Along with this there are Carbon budgets, which provide interim targets as set out in section 2.5. The Renewable Energy Directive (2009) set out a target legally committing the UK to provide 15% of its energy from renewable sources by 2020 (DECC 2011g).

Along with these targets are the policies which help drive them. Two of the main policies set by the EU require the closure of many of the high carbon power stations in the UK. These are: the Large Combustion Plant Directive (LCPD) and its successor the Industrial Emissions Directive (IED).

2.5.1 EU Policy

2.5.1.1 Large Combustion Plant Directive (LCPD)

The LCPD is a European directive, which aims to cut the emissions of certain greenhouse gasses such as sulphur dioxide (SO_2), nitrogen oxides (NOx) and dust (particulate matter) from large power stations in the EU (National Grid, 2007). The UK operators of large generating stations have been given the option of either meeting the requirements of the LCPD emissions or opting out of the emission limit values and accepting limited running hours, closing the stations by the end of 2015 (DEFRA, 2010). This will cause around 12GW of coal and oil fired power stations to close by the 1st January 2016 (National Grid, 2011b Table 2-1). However, under this directive the plants have 20,000 hours of operation which, if used before 2015, will also require the plant to close. Therefore, each plant are likely to use their running hours and shut early if it can make more money this way. This means that the precise timing of closures is not certain making it difficult to plan the replacement stations and therefore impacting on the future security of the system.

Table 2-1 Opted out generation the stations (DECC, 2013i)

Plant	Capacity (MW)	Current Status
Cockenzie units 1 & 2	1,152	Closed March 2013
Cockenzie units 3 & 4		
Didcot A	1,958	Closed March 2013
Ferrybridge	980	Closed March 2014
Ironbridge	940	Open
Kingsnorth	1,940	Closed December 2012
Tilbury (7 & 8)	750	Closed August 2013
Tilbury (9 &10)		
Total (coal)	**7,720**	
Fawley	968	Closed March 2013
Grain	1300	Closed December 2012
Littlebrook	1370	Due to lose by the end of 2015
Total (oil)	**3638**	

2.5.1.2 Industrial Emissions Directive (IED)

The Industrial Emissions Directive IED provides additional tightening to the LCPD on the SO_2, NO_X and particulate limits (Poyry, 2010). It consolidates seven environmental directives including the Integrated Pollution Prevention and Control (IPPC) directive and the Large Combustion Plant Directive (LCPD) into a single directive called the IED (DECC and Ofgem, 2012).

The IED provides relatively long lead times and additional mechanisms with the purpose of being able to find additional investment to fill any loss in capacity (E3G, 2013). The IED provides a number of options: to close a station by January 2016; opt out and continue running for only 17,500 hours from 2016 to 2023; opt in under a transitional plan which will place decreasing emissions targets on the plant up until 2020; or opt in and comply fully by 2016 (DECC and Ofgem, 2012). The age profile of the UK generation stations means that most of the gas power plants are affected. Government says this will impact on up to 40GW of coal and gas, most of which will be able to retrofit abatement equipment to reduce their emissions (DECC, 2012h).

At present the peaks in demand are met by the older power stations, which have the higher variable costs. The LCPD and IED directives dictate that many of these plants will be removed from the system (Newbury, 2011). New capacity will need to be built in order to replace these plants. However, it will be hard to predict their running hours given the potential for zero marginal cost renewable electricity and therefore, finding the investment may be an issue, although this is deeply contentious issue. If it does turn out that investment is not available and so far this has been the case, it may increase security problems if the demand peaks are not reduced. If the coal power plants opt out of the provisions and mechanisms set by the IED, then the potential for investment into new gas is increased whilst leaving coal plant as winter peak capacity (Skillings, 2013). In addition to this the National Grid has been given the power to bring mothballed plant back online if security is threatened (Ofgem, 2013f).

2.5.2 Possible Energy Gap

There is a natural assumption that the future of the electricity system will see an increase in the level of demand. Estimates of the rate at which the demand will increase vary. Figure 2-14 identifies how the different scenarios can generate very different outcomes for a low carbon future. Figure 2-15 identifies a significant drop off in the existing generation capacity (when not using non-consented generation). An example of this loss in generation plant is the opted out generation from EU directives (see Table 2-1) and the current nuclear generating station coming to end of their lives (see Table 2-2). The concern is that the future may see a gap between the level of supply meeting the level of demand.

There are various methodologies which have been suggested in order to combat the potential energy gap. These include extending the operating life of the nuclear power plants (which can be done by the Office for Nuclear Regulation (ONR) (DECC and Ofgem, 2012)). However, extending the plants past their pre-designed lifetime may have consequences for the safety of the plant. Another suggestion is to tackle the problem on the demand side with increased levels of energy efficiency. An additional opportunity is the introduction of increased levels of new generation as is happening with solar (3GW added in last 3 years (DECC, 2014b)). So far the Feed in Tariff has been successful in introducing a large number of new entrants into the electricity system with 379,122 installations as of March 2013 (Ofgem, 2013d) much of which is solar photovoltaic electricity.

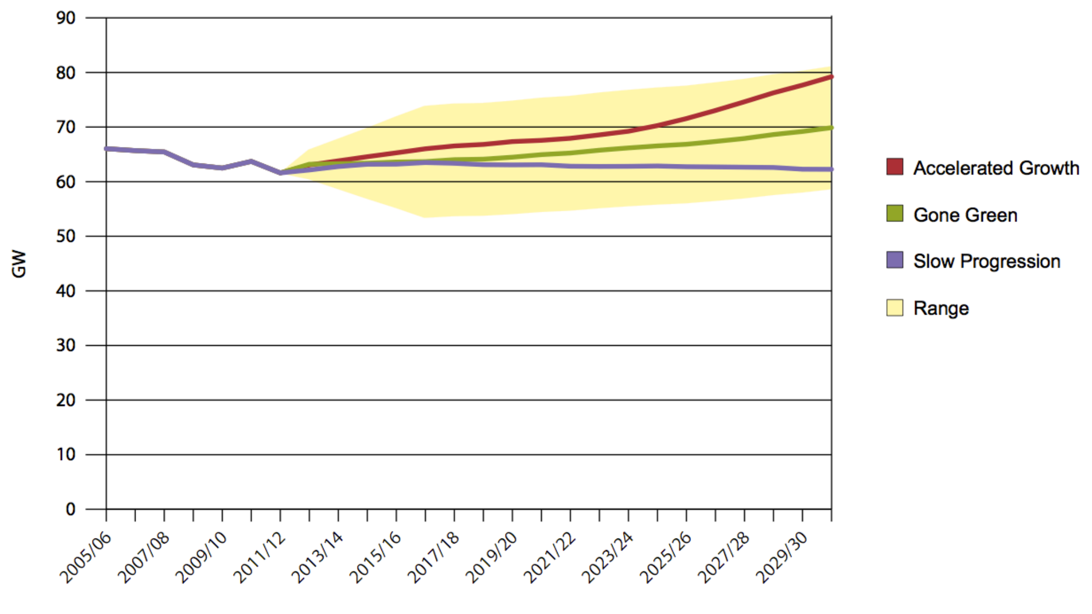

Figure 2-14 Future development of peak demand based on the National Grid UK

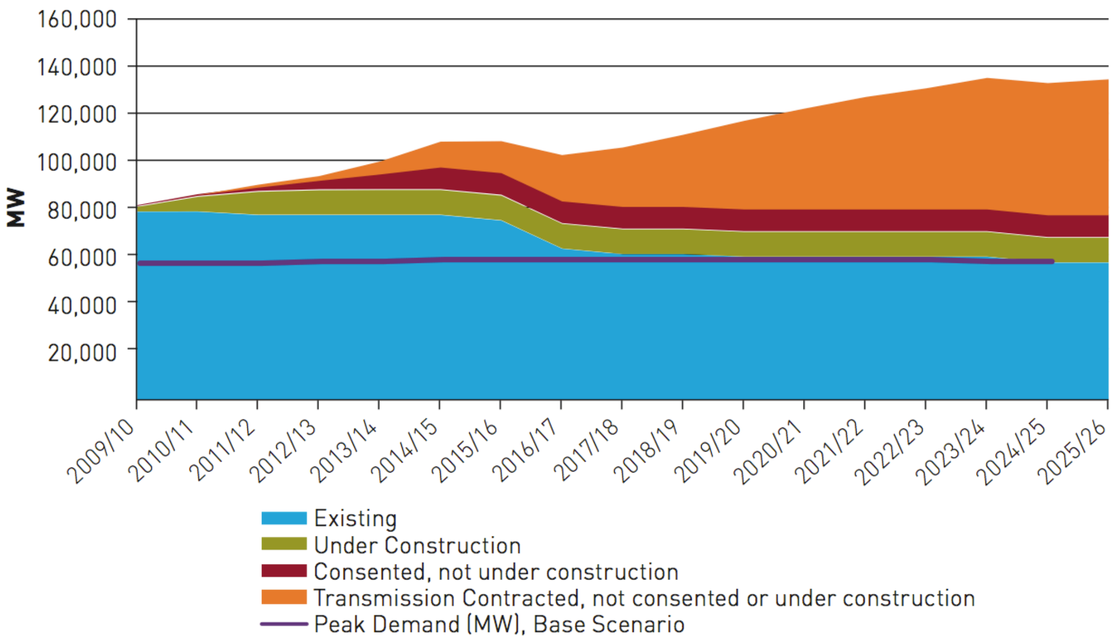

Figure 2-15 Existing and anticipated GB electricity generating capacity (non-derated) (DECC and Ofgem, 2010)

Table 2-2 Closure Schedule of Nuclear power stations (DECC and Ofgem, 2012).

Station	Installed Capacity (GW)	Current expected closure date
Wylfa	1	2012
Oldbury	0.4	2016
Hartlepool	1.2	2014
Heysham 1	1.2	2014
Hinkley Point B	1.3	2016
Hunterston B	1.2	2016
Dungeness B	1.1	2018

2.5.3 Renewables

The UK Government has set out a range of renewable electricity and energy targets over the last decade. The first of these targets were set by the Non-Fossil Fuel Obligation (NFFO) and introduced in 1990. This first target asked for 152MW declared net capacity (DNC) of landfill gas, sewage gas, hydro, wind energy, waste to energy and biomass projects. The second asked for 472MW and the third in 1994 asked for 626.9MW which included biomass gasification for the first time but excluded sewage (Mitchell, 1995). However, the majority of the NFFO levy raised was for nuclear not renewables (typically 98% of the £1.2bn went to nuclear) (Elliott, 2005). This was then replaced by the aim of achieving 10% of the UK's electricity supply from renewables as soon as possible (Kettle, 1999; Mitchell, 1995).

In 2001 a European Directive set an indicative target of 10% gross electricity consumption from renewables by 2010 (EREC, 2009). In the 2007 Energy White Paper the Government set out an aspiration to double this by 2020 (DTI, 2007a). After this, the 2009 EU Renewable Energy Directive set out a target legally committing the UK to provide 15% of its energy from renewable sources by 2020 (DECC 2011g) the equivalent of 30-40% of electricity from renewable sources.

2.5.4 Current Support Mechanisms for Renewables Generation

2.5.4.1 Renewables Obligation

The primary mechanism to drive the uptake of renewables generation in the UK is the Renewables Obligation (RO) Ofgem (2007b). This a market based scheme which was designed with the hope that it will procure renewable electricity at a lower cost compared to feed-in tariffs. This 'pure' market based operation is the largest of its kind in the in the world and began in April 2002 (Toke, 2005).

The RO places a responsibility on licensed electricity suppliers to source an increasing proportion of their electricity from renewable sources (Ofgem, 2012a; ENA, 2010). This proportion started at 3% and rose to 10.4% by 2010 and 15% by 2015.

The RO covers any renewable generation plant whose net capacity exceeds 50kW or is not eligible for the feed-in-tariff (discussed below). It works on a certificate basis whereby the generator receives Renewable Obligation Certificates (ROCs) issued by Ofgem based on the level of generation and the type of technology[8]. These certificates can be traded with other suppliers so that the latter can demonstrate they have met the requirements. The supplier must buy ROCs, if they do not there is a (inflation linked) buy out penalty of 3p/KWh (starting price). This means if the cost of the electricity to the supplier is higher than the buy-out price the supplier will choose not to meet their obligation (Mitchell et al., 2006).

The underlying concept behind the RO is that it is a market-based operation aimed at supporting renewable generation while also keeping the costs to consumers within acceptable limits. However, while the goal of limiting the impact of costs to consumers may have been achieved there was a concern that the level of installation may not be high enough to meet the targets (Elliott, 2005). The doubt over the level of installation was because the suppliers would want to keep the market price of the ROC as high as possible. If the market was flooded with renewable energy then this would lead to a crash in the price of the ROC.

Another concern over the RO is that the renewable energy developers are reliant on the changing price of the ROCs. This means the projects are vulnerable to energy policy changes made by Government which can impact on the market price of ROCs (Wolfe, 2003). This also means that independent generators are exposed to the market price for power. They therefore have to set up purchase power agreements PPA with a supplier which has a built in penalty taking into account the risk of balancing the power (see section 2.1.5).

A further concern with the RO was its limited support for the small scale generation (Hain et al, 2005). Until April 2004 the ROCs were only available to projects over 5MW, eventually the small scale developer was allowed to accrue the annual output and then claim for ROCs. In addition to this the RO is a complex mechanism, meaning the small scale developer would find it difficult to understand and therefore entertain the idea of utilising it. Therefore the UK Government developed the FIT as a mechanism which would deliver widespread deployment of small-scale renewable electricity.

---

8 Initially the RO was 'technology blind' and offered all technologies 1 ROC/MWh. This has subsequently been changed to reflect the different costs and stages of technical development of different renewable technologies.

2.5.4.2 Feed in Tariff

The main support mechanism for small-scale electricity generation are feed-in-tariffs (FITs) (Ofgem, 2012a). The FIT was introduced on 1 April 2010, under the Energy Act 2008, and was designed to encourage low carbon electricity generation through organisations, businesses, communities and individuals who would not normally engage in the energy system and has been a great success from the point of new up-take (DECC 2012i).

The mechanism provides a guaranteed payment from a supplier for all the electricity they generate with an additional payment for unused surplus electricity they export. The supplier then passes on the costs of the scheme (estimated to be £22 for the average householder (DECC, 2013d)) to the consumers. Ofgem maintains the central register and ensures that suppliers comply with the FIT scheme requirements. Is been a very useful mechanism in terms of new entrance to the energy system. At the last count some 379,122 installations generated 1,700 GWh of electricity totalling £506m[9] worth of investment (Ofgem, 2013d).

In 2013, renewables supplied 14.9%[10] share of the UK's electricity requirements (DECC, 2014b). The predicted level of renewable sources up to 2020 is identified in (DECC, 2012m), showing the UK as being nominally on track for the 2020 renewable energy targets. However, as can be seen, after 2012 the line is non-linear and the rate of growth of renewable sources on the system will need to increase, meaning a higher level of capacity deployment from each subsequent year. Without a major increase in investments for renewables the UK is unlikely to meet its renewable energy and electricity targets (PwC, 2010).

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9 Figures as of 31st March 2013
10 This figure include Hydro

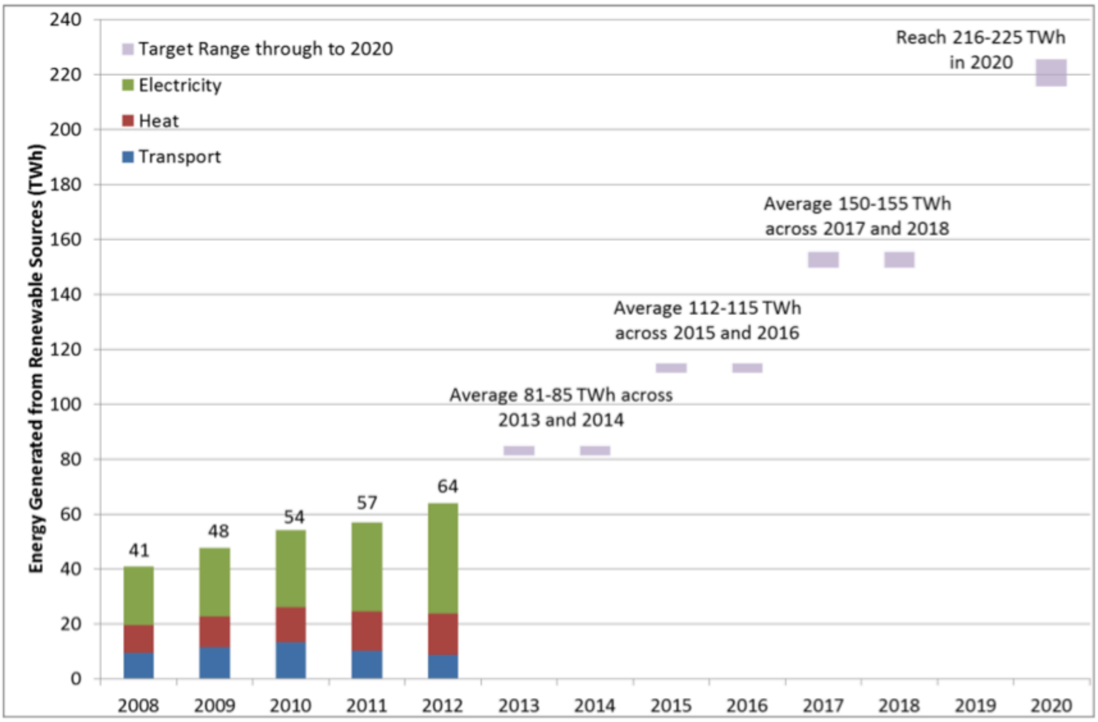


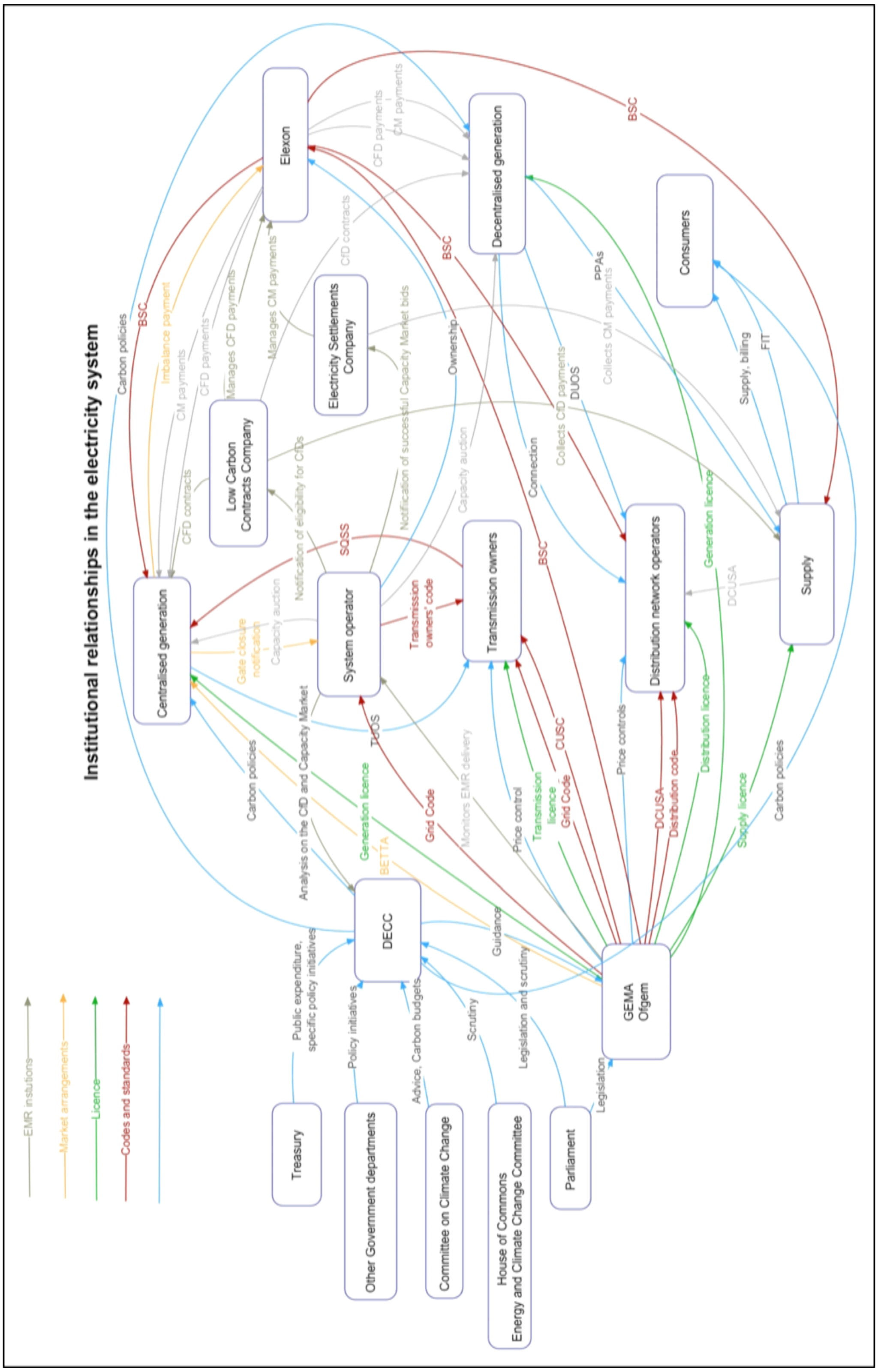
Figure 2-16 Renewable Electricity, Heat and Transport Progress towards 2020 target (DECC, 2013q)

2.6 Key stakeholders in the electricity system

There are a number of key stakeholders in the electricity system. This thesis has identified the Government stakeholders: the Department of Energy and Climate Change, the Treasury, and other Government departments such as Department of Communities and Local Government, the Ministry of Defence and Defra. In addition other stakeholders are, Ofgem, the transmission and distribution network companies, the system operator, ELEXON, the energy companies and consumers. Other relevant groups include the Commons Select Committee and the Committee on Climate change.

Each of these stakeholders and stakeholder groups have are interrelated. The links include market arrangements (including BETTA and the EMR) the codes, standards and the licence arrangements. The arrangement of these relationships are presented in Figure 2-17.

Figure 2-17 Institutional relationships in the electricity system (Woodman, 2014)



2.6.1 Department of Energy and Climate Change (DECC)

DECC was created in 2008 by the merging of the energy policy elements of the Department for Trade and Industry and some climate policy elements from the Department of the Environment, Food and Rural Affairs. The Secretary of State (currently Rt Hon Ed Davey MP) is a member of Cabinet; there are three other Ministers of State.

The Department's stated purpose is to *"to make sure the UK has secure, clean, affordable energy supplies and promote international action to mitigate climate change".* Within this very broad statement, DECC has several areas of responsibility, including energy security and promoting renewable energy.

DECC follows standard Government processes when designing policies, with an emphasis on engaging stakeholders and consulting widely on new policies or amendments to existing ones. The processes involved in these stakeholder engagement activities are set out in the Cabinet Office's Consultation Principles document (Cabinet Office, 2013) which sets out the rationale for consultation as (p1):

> *to garner views and preferences, to understand possible unintended consequences of a policy or to get views on implementation. Increasing the level of transparency and increasing engagement with interested parties improves the quality of policy making by bringing to bear expertise and alternative perspectives, and identifying unintended effects and practical problems*

Clearly, widespread participation from stakeholders when designing policy has the advantage of using existing expertise and judgement on what may or may not be practical and successful. However, it also inevitably means that stakeholders will argue for policies, or for details of policies, which support their best interests. This becomes an issue when some groups of stakeholders have more power than others, or when stakeholders seek to exclude other views even if they would be more effective in meeting broader policy goals. An example of this could be Government not acknowledging the views held within a consultation process (Florini and Sovacool, 2009).

2.6.2 Treasury

Although DECC has responsibility for delivering the policy and measures intended to meet the Government's energy goals, its activities take place within the broader framework of overall Government activities, and in particular economic and fiscal policies. HM Treasury is responsible for the UK's economics and financial policies designed to maintain control of public spending, and to contribute to the growth of the UK's economy. In delivering these objectives, the Treasury works closely with all Government departments, and therefore has a clear but indirect influence on the activities of DECC.

In addition, however, the Treasury is also directly involved in energy policy decisions. These include investment in major infrastructure projects, and the provision of Government guarantees to underwrite major private sector projects, including the construction of a new nuclear power station at Hinkley Point C. These are co-ordinated by Infrastructure UK, a unit within the Treasury.

In addition, the Treasury has a degree of control over funding for various subsidies designed to support deployment of low carbon technologies, including the Renewables Obligation. Energy companies pass the costs of meeting their obligations to invest or buy low carbon technologies on to consumers. The Levy Control Framework (LCF) is agreed between the Treasury and DECC and designed to limit the impact of these subsides (levies) on consumers by imposing an annual cap on how much will be spent.

The Treasury also has responsibility for setting the price of carbon for the Government's Carbon Price Support (CPS) mechanism. The CPS is intended to ensure that the fluctuations in the price of carbon seen in the EU Emissions Trading Scheme are levelled out by imposing a minimum annual carbon price, known as the Carbon Price Floor[11]. The difference between the CPF and the actual price of carbon in the EUETS is 'topped up' by large energy users, with this difference known as Carbon Price Support (Figure 2-18). As a way of maintaining the effectiveness of the incentive and of enhancing investor certainty, the price floor is meant to rise each year, with announcements made about future levels made 2 years in advance. The CPS was introduced in 2013, with a CPS level of

11 The CPS mechanism is administered by HM Customs and Excise and works in conjunction with the Climate Change Levy

£4.94/tCO2 (HM Revenue and Customs, 2013). This level was expected to rise to £30/tCO2 by 2020.

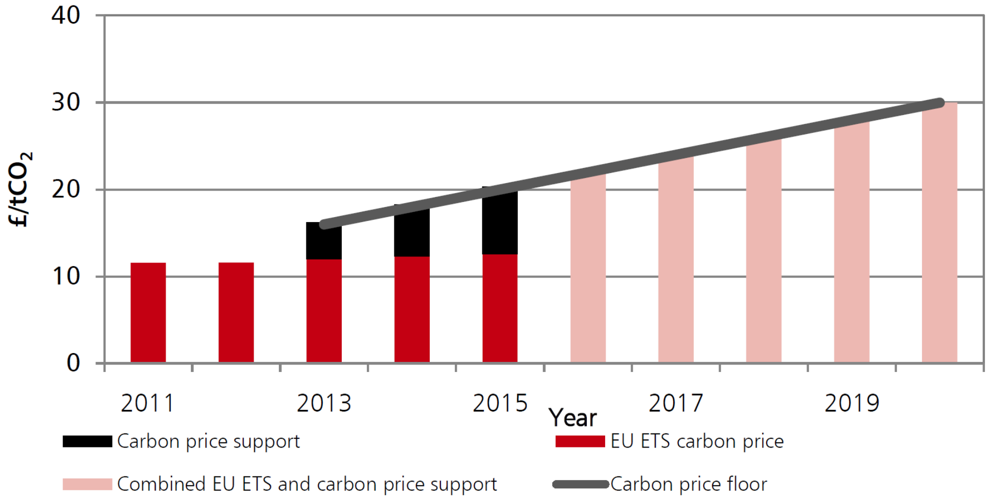


Figure 2-18 Carbon price floor illustration (in real 2009 prices and calendar years) Source HM Treasury (2011)

The intention behind the mechanism is to try to maintain incentives to invest in low carbon technologies by removing the uncertainties about the future price of carbon. However, the 2014 Budget froze the level of the floor, rather than allowing the expected increase on the grounds that carbon prices in the EUETS were lower than expected and that by allowing an increase in the price of carbon in the UK, business would be damaged in comparison with other European countries (Murray, 2014).

The Treasury therefore has a significant role in the delivery of the UK's energy policy aims, although this is not always explicit or direct. Under the coalition, the Chancellor has displayed a degree of reluctance to advance low carbon technologies, while also putting in place measures which maximise the exploitation of fossil fuels in the North Sea, as well as enthusiastically promoting fracking as a source of natural gas.

2.6.3 Other Government departments

Although less significant than the Treasury in the implementation of energy policy, there are several over departments which can also directly or indirectly influence DECC's work. These include:

Department for Environment Food & Rural Affairs, Department of Communities and Local Government, which is responsible for planning guidance for renewable projects (DECC, 2013p), and the Ministry of Defence, which is also an integral part of the planning process and has objected to several renewable projects on the grounds that they might interfere with operations.

2.6.4 Ofgem

2.6.4.1 Ofgem's role

The regulation of the energy sector was originally organised by two separate agencies, Office of Electricity Regulation (OFFER) and Office of Gas Supply (Ofgas) until 2000 when Ofgem was formed. Ofgem is a non-ministerial Government department which works with Government but is independent from it. Its work falls into two main areas: the design and regulation of gas and electricity markets, including licensing energy supply companies, and regulating the financial aspects of the monopoly transmission and distribution network companies. It carries out these activities within a broad framework of duties established through legislation.

The 1989 Electricity Act conferred three main duties on the Secretary of State and the Director General of OFFER (Part 1 Section 3) (Electricity Act, 1989):

> *(a) to secure that all reasonable demands for electricity are satisfied;*
>
> *(b) to secure that licence holders are able to finance the carrying on of the activities which they are authorised by their licences to carry on; and*
>
> *(c) subject to subsection (2) below, to promote competition in the generation and supply of electricity.*

The Act also contained subsidiary duties largely focused on protecting consumers and ensuring the safety of the electricity system. While security of supply is not explicitly mentioned, it is clearly an implicit part of the duties to ensure that reasonable demands are met, and that licence holders can finance their activities.

Over time the duties imposed on the regulator have changed, both substantively and in terms of emphasis. A key change came with the Utilities Act 2000, which established the Gas and Electricity Markets Authority (GEMA) as the economic regulator of the gas and electricity industries in Great Britain. The Act also established a new regulatory agency – Ofgem, formed by the merger of OFFER and Ofgas - as GEMA's executive arm[12].

The Utilities Act set out the functions of the gas and electricity markets and imposed a new primary duty on the regulator authority Ofgem to protect the interests of consumers in relation to electricity and gas (Utilities Act, 2000; Rutledge, 2007).

> *"to protect the interests of consumers in relation to electricity conveyed by distribution systems, wherever appropriate by promoting effective competition between persons engaged in, or in commercial activities connected with, the generation, transmission, distribution or supply of electricity or the provision or use of electricity interconnectors" (Utilities Act, 2000: 3A [1])*

The promotion of competition was therefore established as the key focus for the regulator, with the other duties originally set out in the Electricity Act 1989 effectively relegated to a lesser status. Further adjustments to the role and duties of the regulator have been contained in the Competition Act 1998, the Enterprise Act 2002 and the Energy Acts of 2004, 2008, 2010, 2011 and 2013. These adjustments reflect in particular a concern with the sustainability of energy systems, reflected in a change to the primary duty that it should *"protect the interests of existing and **future** consumers".* GEMA's duties as they currently stand are set out in Box 2.1 (Ofgem, 2013b)

12 Although GEMA and Ofgem are separate bodies, it is common to refer to both as just Ofgem – see for example DECC energy Bill provisions 2012. This thesis will also adopt this practice unless it is necessary to distinguish between the two institutions.

Box 2.1: Powers and duties of GEMA

The Authority's principal objective is to protect the interests of existing and future consumers in relation to gas conveyed through pipes and electricity conveyed by distribution or transmission systems. The interests of such consumers are their interests taken as a whole, including their interests in the reduction of greenhouse gases in the security of the supply of gas and electricity to them and in the fulfilment by the Authority, when carrying out its functions as the designated regulatory authority for Great Britain, of the objectives set out in Article 40 (a) to (h) of the Gas Directive and Article 36 (a) to (h) of the Electricity Directive. The Authority is generally required to carry out its functions in the manner it considers is best calculated to further the principal objective, wherever appropriate by promoting effective competition between persons engaged in, or commercial activities connected with,

- the shipping, transportation or supply of gas conveyed through pipes
- the generation, transmission, distribution or supply of electricity
- the provision or use of electricity interconnectors

Before deciding to carry out its functions in a particular manner with a view to promoting competition, the Authority will have to consider the extent to which the interests of consumers would be protected by that manner of carrying out those functions and whether there is any other manner (whether or not it would promote competition) in which the Authority could carry out those functions which would better protect those interests.
In performing these duties, the Authority must have regard to:

- the need to secure that, so far as it is economical to meet them, all reasonable demands in Great Britain for gas conveyed through pipes are met;
- the need to secure that all reasonable demands for electricity are met;
- the need to secure that licence holders are able to finance the activities which are the subject of obligations on them; and
- the need to contribute to the achievement of sustainable development.

In performing these duties, the Authority must have regard to the interests of individuals who are disabled or chronically sick, of pensionable age, with low incomes, or residing in rural area
Subject to the above, the Authority is required to carry out the functions referred to in the manner which it considers is best calculated to:

- promote efficiency and economy on the part of those licensed under the relevant Act and the efficient use of gas conveyed through pipes and electricity conveyed by distribution systems or transmission systems
- protect the public from dangers arising from the conveyance of gas through pipes or the use of gas conveyed through pipes and from the generation, transmission, distribution or supply of electricity; and
- secure a diverse and viable long-term energy supply, and shall, in carrying out those functions, have regard to the effect on the environment.

In carrying out these functions the Authority must also have regard to:

- the principles under which regulatory activities should be transparent, accountable, proportionate, consistent and targeted only at cases in which action is needed and any other principles that appear to it to represent the best regulatory practice; and
- certain statutory guidance on social and environmental matters issued by the Secretary of State.

The Authority may, in carrying out a function under the Gas Act and the Electricity Act, have regard to any interests of consumers in relation to communications services and electronic communications apparatus or to water or sewerage services (within the meaning of the Water Industry Act 1991), which are affected by the carrying out of that function.

The Authority must carry out its functions in the manner that it considers is best calculated to implement or ensure compliance with any decision of the Agency or the European Commission under the Third Package and, when carrying out its functions as the designated regulatory authority, consult and cooperate with the Agency and other designated regulatory authorities whenever it thinks fit.

The Authority has powers under the Competition Act to investigate suspected anti-competitive activity and take action for breaches of the prohibitions in the legislation in respect of the gas and electricity sectors in Great Britain and is a designated National Competition Authority under the EC Modernisation Regulation and therefore part of the European Competition Network. The Authority also has concurrent powers with the Office of Fair Trading in respect of market investigation references to the Competition Commission.

The evolution of the role and duties of GEMA (and therefore Ofgem) is a reflection of shifting political priorities together with increasing political awareness of the complexity of electricity systems and the difficulty of meeting the UK's three key energy policy goals (see section 2.4). This is shown by the increasing level of qualification relating to the principal objective of encouraging competition: over the years this has changed to a much more complex, multi-dimensional requirement to balance competition against over policy goals, albeit with competition always the primary aim (Box 2.1).

As the responsibilities of the institution have changed, uncertainty about the respective roles of Ofgem and DECC has become increasingly apparent, as recognised by DECC's review of Ofgem which reported in 2011:

> *While the fundamentals of the regulatory system remain sound, the breadth of the contribution that the energy sector is now expected to make to wider policy goals and the scale of the challenge ahead has made the world of 2011 very different from that of the 1980s. As Ofgem's role has become more complex, there has been a blurring of responsibilities between Government and Ofgem causing some erosion of the regulatory certainty that independent regulation was designed to provide. There is a need for an enduring solution that sees Government clearly taking responsibility for setting and communicating strategic direction, Ofgem's independent regulatory decisions forming a logical and coherent part of this broader strategic policy framework, and ad hoc interventions avoided where possible. (DECC, 2011p. pg:6)*

This blurring of the lines between Government and regulator is particularly apparent in relation to social and environmental issues, and the degree to which Ofgem may or may not be responsible for helping meet the Government's targets, for example by enabling greater deployment of renewable technologies as a contribution to carbon emission reductions.

The blurring is also apparent in relation to energy security and the tension between encouraging competition as a means of delivering relatively low cost power, and the need to drive investment in new capacity in an uncertain and competitive electricity market. DECC's Ofgem Review seeks to clarify the role of Government and of Ofgem and concluded that (DECC, 2011p. Paras 83 and 85):

> *The Review concluded that wider public interest goals should remain embedded in Ofgem's duties: it is right that Ofgem should consider trade-offs between economic and broader goals in all its decision making. However, Ofgem's responsibilities should not be broadened: it is Government that should make trade-offs at the strategic level where the general interests of citizens are at stake. Ofgem's actions should be coherent with the direction set by Government, recognising that there will still be trade-offs that Ofgem will need to make at the level of regulatory decision-making.*
>
> *With the duties remaining essentially unchanged, it was necessary to consider other ways for Government to better communicate its strategic vision and associated high-level policy decisions to the regulator.*

As a result of the need for greater clarity, the Government is now required to issue a Strategy and Policy Statement (SPS) setting out strategic goals for gas and electricity. This gives a description of roles and responsibilities for Government, Ofgem, business and other organisations in the energy market, and clarifies the policy outcomes against which Ofgem must weigh its regulatory decision making. This requirement was established in the Energy Act 2013, and an initial draft is expected sometime in 2014. The SPS will contain an outline of DECC's view of the need for energy security and a breakdown of the policy outcomes which Ofgem would be required to assess its actions against. This has the potential to be a significant step in the governance of energy security as well as other elements of energy policy. It should lead to greater clarity of how energy policy goals are being delivered and a framework against which the activities of Ofgem can be judged.

2.6.4.2 Ofgem and energy security

Ofgem is now required to report to the Secretary of State every year giving its assessment of the threats to electricity security of supply in Great Britain. The Electricity Capacity Assessment evaluates a set of electricity capacity margins that could be delivered by the market over the next five winters and assesses what the risks to security of supply might therefore be[13] (Ofgem, 2013c). The reports are based on National Grid's Future Energy Scenarios (FES) work (National Grid, 2014), which looks at four different possible futures for the electricity market up to 2035 and 2050, and is augmented by Ofgem's own sensitivity analysis of various uncertainties relating, for example, to high levels of demand as a result of cold weather conditions or reduced availability of gas plant.

The Future Energy Scenarios are discussed in more detail below (see section 2.7.1.1). The most recent Electricity Capacity Assessment (2014) shows the reduction in de-rated capacity margin as most acute in 2015/16 as a result of plant closures. These is an improvement after that as new plants come on line and some mothballed plants return to operation (Figure 2-19).

13 Ofgem uses an assessment of the de-rated capacity margin, which is the average amount of additional electricity that will available compared to winter peak demand. This gives an overall picture of trends in the electricity sector but does not identify specific risks to security of supply. The reports also consider Loss of Load Expectation (LOLE), which is the estimated number of hours that supply is expected to be lower than demand each year. This is not necessarily about power cuts, but does indicate when action might need to be taken to reduce demand.

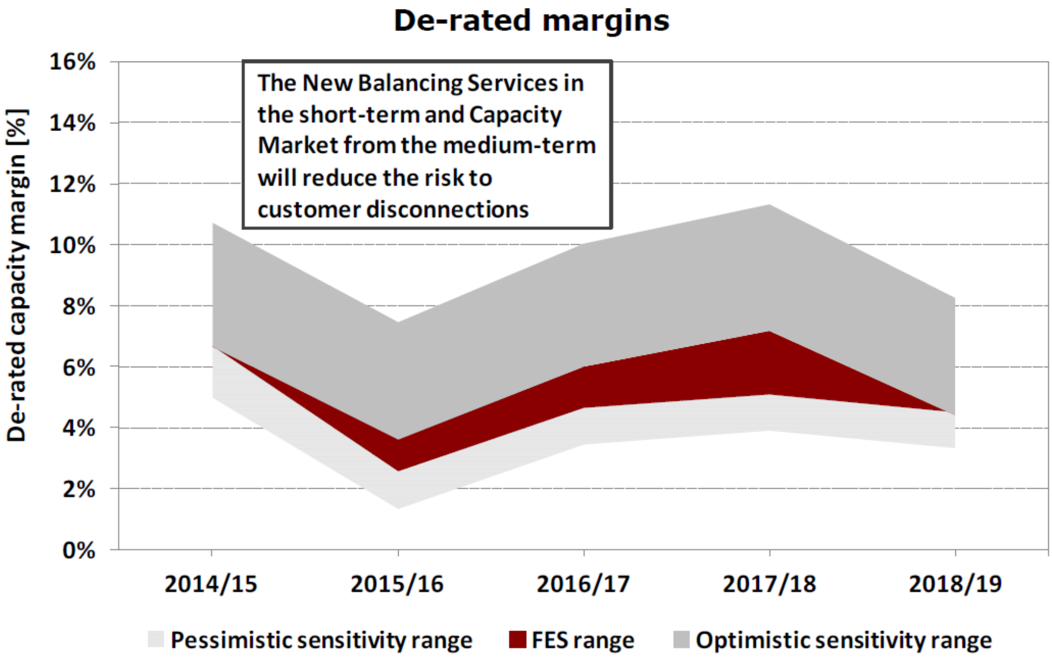


Figure 2-19 De-rated capacity margins 2014/15 to 2018/19 (Ofgem, 2013c pg:5)

While the Electricity Capacity Assessment reports can create a media stir when they are published, given the possible reduction in capacity margin in the coming years, it is important to remember that they are scenarios based on other scenarios and so are intended to provide a range of possibilities for policy makers to consider, rather than predictions of what is going to happen. The other key point to make about the reports is that they are intended only to provide information for decision makers, and do not contain any specific policy or regulatory measures themselves.

2.6.4.3 Ofgem and Decentralised Generation

Ofgem does not have a formal role in promoting decentralised generation, but it does see its role as actively ensuring that decentralised electricity is not unfairly disadvantaged by the regulation and operation of distribution networks. As part of this, it hosted 3 Distributed Generation Forum events in 2012 as a way of engaging generators and DNOs in an effort to improve arrangements.

2.7 Network Companies

Network companies can be broken into two groups; transmission and distribution. The high voltage (275 and 400kV) transmission network in England and Wales is solely owned by the National Grid Company. The transmission network in Scotland is owned by SSE and SP Energy Networks, a subsidiary of Scottish Power and include 132kV lines as well as 275kV and 400kV (See Figure 2-20).

2.7.1 Transmission network operators

The primary function of the transmission network is to deliver electricity from large generating stations to the distribution networks. The transmission network owner is responsible for building, maintaining, and managing the networks. In addition, the recent deployment of offshore wind farms has led to the creation of new transmission network companies in England, Wales and Scotland. National Grid Electricity Transmission plc (NGET) is the transmission owner for the England and Wales system. Its operating costs are recouped by charging generators and consumers Transmission Network Use of System charges[14].

14 The tariffs for these are set annually, and are zonal, with different generator and consumer charges depending on the geographic location. This reflects the fact that demand for power tends to be higher in the south, while generation is more available in the north. As a result, there is a north-south flow of electricity, and consumers in the south pay a higher tariff, while in the north it is generators rather than consumers who have the higher tariff.

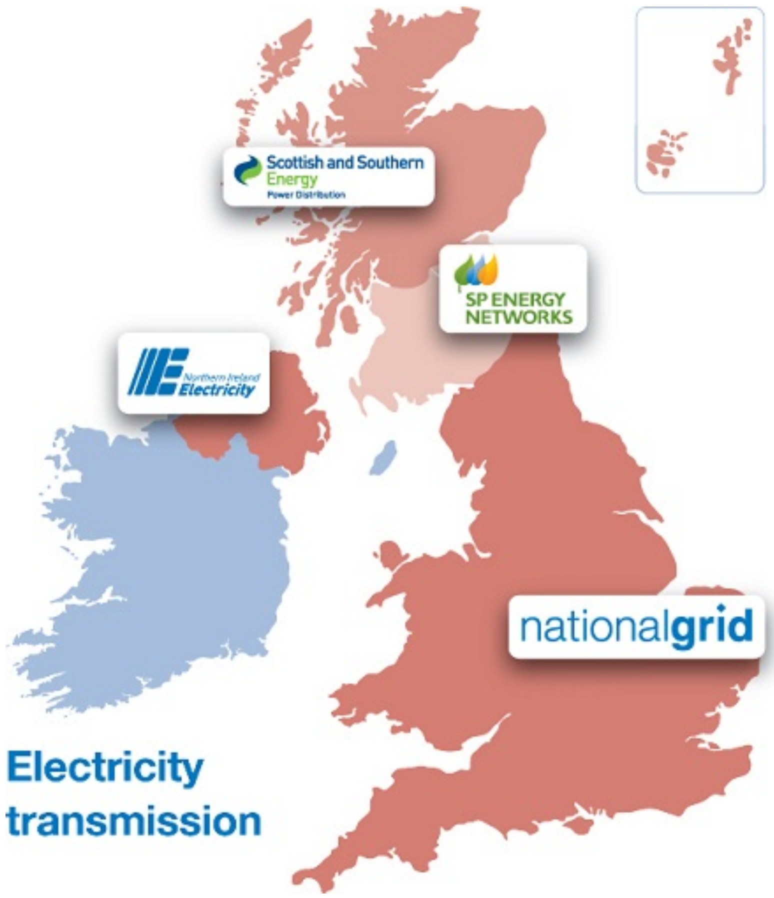


Figure 2-20 Map of Transmission Network Owners in the UK

In addition to maintaining and operating the transmission networks, National Grid is the administrator for the National Electricity Transmission System Security and Quality of Supply Standards (NETS SQSS). These set out a set of criteria and methodologies that Transmission Licensees (both onshore and offshore) use in planning connections and operation of the transmission network (National Grid, 2012). Briefly, the criteria define what are acceptable modes of operation, what should happen in case of a fault, and what criteria generators have to fulfil in order to connect to the transmission network. The SQSS is designed to maintain the overall security of the system by defining the acceptable limits of plant performance. However, in doing so they are reflecting the qualities of predictability and reliability which are associated with conventional generation, but which are not necessarily a feature of variable renewable plants (UKERC, 2006).

2.7.1.1 National Grid's Future Energy Scenarios

As mentioned earlier, the National Grid Company produces annual scenarios to inform decision making on the development of the gas and electricity systems. The scenarios are meant to be relevant to Government, customers and other stakeholders as well as the National Grid; however, the emphasis is on network development rather than on all aspects of system development and operation.

The most recent Future Energy Scenarios (FES) are based around the potentially conflicting affordability and sustainability dimensions of electricity supply. Within this framework, four scenarios have been developed reflecting different possible implications of differing levels of commitment to these aims (Figure 2-21). In the context of this thesis, the individual storylines are not particularly relevant. The key point to make is that the future development of decentralised energy is explicitly considered in these scenarios. The projections for future DE capacity in 2035/36 ranges from 17.6GW in the No Progression scenario to 26.3GW – nearly 20% of all installed generation capacity - in the Low Carbon Life scenario.

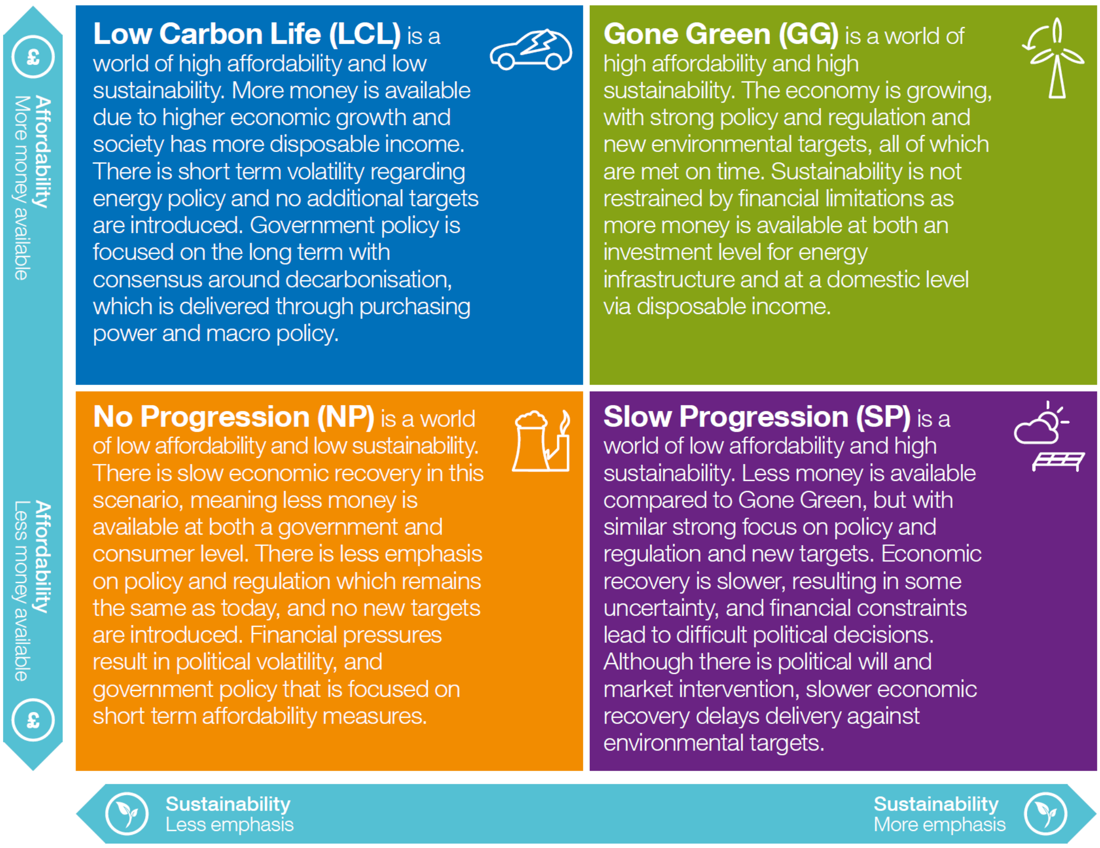


Figure 2-21 Outline of the Energy Scenarios (National Grid, 2014)

There is, however, no detail on the implications for network development, nor a consideration of the overall impacts of increased levels of decentralised electricity for system management and operation. This is significant in that neither National Grid's scenarios, nor their application in Ofgem's Electricity Capacity Assessment report, deal with the systemic implications of increasing levels of decentralisation, nor address the possible security consequences of this.

2.7.2 Distribution network operators

The distribution networks are broken into twelve regional networks in England and Wales, and a further two in Scotland. The England and Wales networks are owned by seven different companies (Figure 2-22). The Distribution Network Operators (DNOs) distribute electricity from the transmission grid to homes and businesses using 132 kV, 33 kV, 11 kV and 230 V lines.

In addition, there are six Independent Distribution Network Operators who own and operate smaller networks located within the areas covered by the DNOs[15]. IDNO networks are mainly extensions to the DNO networks serving new housing and commercial developments. IDNOs are essentially regulated in the same way as DNOs, including a 'Relative Price Control' which caps what they charge their customers at a level broadly consistent with the DNO equivalent charge.

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15 Energetics Electricity Limited, ESP Electricity Limited, Independent Power Networks Limited, The Electricity Network Company Limited, UK Power Networks (IDNO) Ltd and Utility Assets Limited

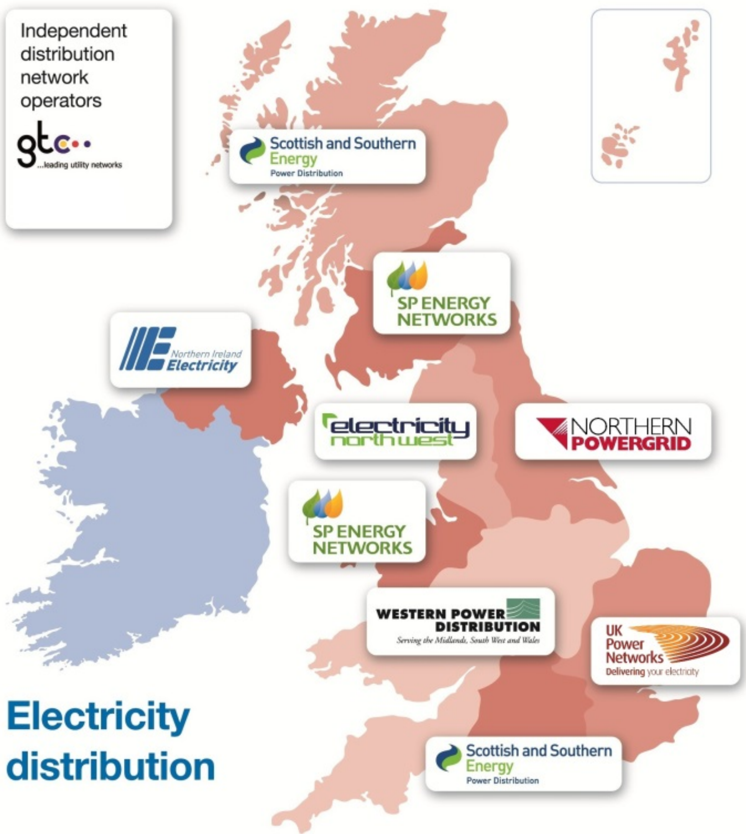

Figure 2-22 Electricity Distribution Map (ENA, 2013)

DNOs will be key players in a more decentralised energy world. Not only will they operate the networks in a more 'active' way, but generators who wish to connect will have to rely on them to consent to those connections and enable their power to be exported. As regulated monopolies, the design of the regulatory rules which create incentives or disincentives for allowing more generation to connect to the networks has a central role to play.

2.8 The System Operator

As well as owning transmission network assets in the England and Wales system, National Grid also acts as the System Operator (SO) for the National Electricity Transmission System (NETS) in the whole of Great Britain. The system operator is required to have an entirely separate operation from National Grid. The SO has a responsibility to provide short-term generating provision, which covers anomalies in demand prediction and technical failures in generation, and also ensures that the balancing of the systems stays within the technical limits. The SO also has a licence obligation to ensure that sufficient capacity is available to meet demand. It achieves this in a number of ways, including:

- Buying or selling electricity in the Balancing Mechanism
- Buying or selling electricity through Trading
- Entering into contracts for Balancing Services

The balancing and settlement arrangements and their governance are enshrined in the Balancing and Settlement Code (collectively known as the BSC arrangements). The requirement to have the BSC in force is placed on National Grid through its Licence and managed by ELEXON.

2.9 ELEXON

ELEXON is a not-for-profit organisation with National Grid as the sole shareholder. However, NG operates as a passive shareholder with ELEXON being managed by its board of 12 members made up of energy industry representatives (ELEXON, 2012, Ofgem, 2011c). ELEXON's role is to deliver the Balancing and Settlement Code (BSC) on the industry's behalf and requires it to manage service contracts and handle trading disputes and enforce performance standards. All the major energy companies are signatories to the BSC and therefore, linked to ELEXON, including its funding process. ELEXON interacts with over 200 companies and almost £1.5bn of funds.

2.10 Energy Companies

2.10.1 The Big Six

The GB electricity generating and supply sector is dominated by six companies, known collectively as the Big Six. Collectively, the Big Six own a little over 70% of GB electricity capacity, and supply around 95% of domestic energy consumers. The Big Six are: Centrica-owned British Gas, EDF Energy, npower, E.ON UK, Scottish Power, and SSE. Although supply is much more diverse in the business and industrial sectors (DECC 2013q; Ofgem, 2014b; Cornwall Energy, 2014).

2.10.2 Independent generators and suppliers

Around 30% of UK generation is not owned by the Big Six. Some of this independent generation is conventional, centralised generation such as Rugeley and Drax coal stations, which are owned by International Power and Drax Power respectively . Around 14% of current GB capacity is owned by non-Big Six companies and is decentralised (DECC, 2013g).

2.11 Consumers

Different consumer groups such as industry, commercial business and individual households approach the electricity system with very different perspectives on energy and therefore, there is no single socially shared concept of energy (Devine-Wright, 2007). Without consistency of knowledge a lack of development and engagement, this immense actor group currently appears to find it difficult to mount any type of effective change to the system (ECCC, 2012).

A possibility within this monolithic view of consumers is that eventually the individual's attitudes towards how the system should operate will become more prevalent. This could possibly be encouraged through an increase in communities of individuals with similar ideologies such as the Transition Towns movement, community energy projects or city energy projects (IPPR, 2014), providing the drive and ability to try and change the system. Society (via individuals and communities) can also increase its impact on the energy system by becoming more engaged with the operation and decisions of the energy system and therefore becoming more of an influence on the decision makers.

The introduction of the FIT has provided the individual householder with the ability to engage with the energy system. Clearly, with an increased level of engagement by individuals, the governance of the energy system would change and the dynamics may be altered, reducing the power of the main energy companies. Possibly more importantly, the economics of energy appear to be changing causing decentralised technologies to be more competitive. Increasing decentralisation will increase consumer involvement and connection with energy (CITI, 2013).

2.11.1 Prosumer Movement

The evolution of the 'prosumer' has been argued to be able to revolutionise the traditional centralised electricity generation model to more interactive decentralised electricity system which changes the role and responsibility of the consumer (IEA-RETD, 2014).

The term prosumer is a reference to consumers who produce their own power. This is dominated by the use of renewable electricity technologies such as solar pv and wind but can also include other forms of local generation such as diesel generators and combined heat-and-power systems. The prosumer has evolved due to a shift in public perception of the use of traditional technologies and fuels for electricity generation. This shift comes from a number of reasons such as economics, a price reduction in renewable generation (namely from government subsidies). Behavioural changes have also occurred stemming from environmental concern over climate change or international impacts such as the Fukushima nuclear disaster in Japan.

One of the main drivers for the prosumer movement is that the technology is now available for the consumer to produce power themselves. Specifically with solar PV, technology has allowed greater interaction for consumers and flexibility ultimately changing the role and responsibility of consumers and the institutions involved. PV in particular has been characterised as a disruptive technology which can revolutionise the electricity industry in the same way that the computer or the mobile phone changes their respective sectors (Schleicher-Tappeser, 2012)

The impact solar PV has had on the electricity system is that it is the closest renewable technology to reaching market parity. It has been suggested that this will happen in the UK by 2020 (DECC, 2014e, Elliott, 2014). What needs to happen is, the policy makers recognise and anticipate the development of the prosumer market. They also need to evaluate the benefits and costs both financial and non-quantifiable of a prosumer movement.

2.12 Other Relevant Groups

2.12.1 Commons select Committee

The Commons Select Committees are generally responsible for overseeing the work of Government departments and agencies. The Energy and Climate Change Committee was established following the launch of the Department of Energy and Climate Change in 2008 (Parliament, 2008). The committee was set up by the House of Commons to examine the expenditure, administration and policy of the Department of Energy and Climate Change and its associated public bodies.

They have no direct influence on Government policy; their role is far more subtle. Their influence on the policy process cannot be measured. However, Russell and Benton (2011) provide seven different ways in which the committee can impact on the system: contributing to debate, drawing together evidence, spotlighting issues, brokering between actors and government, improving the quality of government decision-making through accountability, exposing failures, and perhaps most importantly 'generating fear'.

2.12.2 Committee on Climate Change

The Committee on Climate Change (CCC) was established under the Climate Change Act 2008. It is an independent body whose role is to advise UK Government and Devolved Administrations on emissions targets. It also reports to Parliament on the levels of emission reductions associated with climate change (CCC, 2013a). The CCC has a set of strategic priorities which include advising Government on its carbon budgets, monitoring emissions reductions, analysis of climate change science and policy, and engage with organisations and individuals to disseminate the analysis.

Therefore the CCC does not have the ability to change policy or any activity in the direct decision-making. However, it does provide the information and analyses the data for decision makers. This advisory role to the Government means that the approach the CCC takes may have a substantial impact on the decisions made by Government. In addition to this the CCC provides information to individuals regarding climate change, the level and approach taken to this can impact on the decisions made by consumers.

2.13 Summary

This chapter has identified the main changes to the electricity system over the last quarter of a century. This has included the privatisation of the UK energy system and it impacts from the dash for gas to the changes in the retail and wholesale markets. This has included the move from the Pool to NETA and then to BETTA.

In addition to this it has identified the main features of the Electricity Market Reforms, announced for the UK electricity system. This includes the impact of the CfDs on the variable technologies such as wind and solar power, which have different rules under the CfDs than that of baseload nuclear generation stations. It also identifies the Capacity Market as the Government's way of ensuring future supply security, however, it is clear that this mechanism focuses on the large scale generation, thus promoting centralised technologies over smaller scale decentralised generation.

With the understanding of the market operation set out this chapter then identified the regulation of the networks focussing on the future of regulation through RIIO.

The development of the electricity system including the changes to the markets and regulatory structure, are driven by the UK Governments policies, goals and targets. The main goals can be considered as a trilemma of climate change, affordability and energy security. In order to meet these goals there are sets of targets for carbon reduction and renewable deployment. The EU has established directives, which will ensure the carbon efficiency of the electricity generating plants called the LCPD and IED. The point to be aware of is that by closing GB power plants due to old age or for environmental reasons, the future capacity levels may not be able to meet rising levels of demand and energy gap may develop. This describes the conflict inherent in pursuing the various goals of Government.

This chapter finished by setting out the key stakeholders in the electricity system. These include the Government groups such as the Department of Energy and Climate Change, the Treasury and other smaller Governmental Groups. These Governmental groups are responsible for setting the policy framework for future goals as set out in the Government White papers. Further to this they have a role in dictating the investment portfolio for the electricity system specifically for a low carbon future, this is at present set though the EMR as discussed in section 2.2. They are also responsible for the short term capacity levels, where the amount of capacity to be auctioned in the capacity mechanism is decided by the Minister of Sate (DECC). Government also has a responsibility to set the duties and give guidance to the regulator.

Although, government departments such as DECC have to follow standard procedure in that they have to consult widely on new policies or amendments to existing ones. Further to this it is the treasury who look after the UK's economics and financial policies designed to maintain control of public spending. This means they have a degree of control over funding for various subsidies designed to support deployment of low carbon technologies, including the Renewables Obligation.

This chapter also discussed Ofgem, its role in the electricity system, in energy security and in relation to small-scale generation. Ofgem are responsible for ensuring appropriate regulation for the transmission and distribution network operators, the system operator and for all costs and licences. Ofgem's principal objective is to protect the interests of existing and future consumers in relation to gas conveyed through pipes and electricity conveyed by distribution or transmission systems.

This section also described the network companies, including the distribution network owners and transmission network owners which for England and Wales, is the National Grid who also fulfil the role of the System Operator (as a wholly separate aspect of the NGC). The distribution networks are broken into twelve different regions England and Wales owned by seven companies. The key role at present for the DNO's is to operate and maintain their networks. However, it is likely that in a future of decentralised electricity generation their role will change dramatically. The transmission network owner is responsible for building, maintaining, and managing the networks, with a primary function of delivering electricity from large generating stations to the distribution networks. For England and Wales the TNO is the National Grid Company who have an additional role of acting as the System Operator (SO) for the National Electricity Transmission System (NETS) in the whole of Great Britain (although it's role as SO designed to be entirely separate from the National Grid).

The SO has a responsibility to provide short-term generating provision, which covers anomalies in demand prediction and technical failures in generation, and also ensures that the balancing of the systems stays within the technical limits. The SO also has a licence obligation to ensure that sufficient capacity is available to meet demand.

This chapter discussed the energy companies role and the dominance of the big 6 energy companies who hold around 70% of the generation profile and 95% of the domestic supply industry. The responsibility of these large utility companies is to their shareholders and to the contracts set up with their consumers.

It then described the role of the consumers as well as other relevant groups such as the Commons Select Committee and the Committee on Climate Change. The consumer groups is a large collection of different consumers from domestic householder, business and industry each with different perspectives on energy. The current view of the consumer is that of simply paying for the electricity used and having very little input into the operation of the energy system.

However, with the increase in FIT uptake over the last few years there has been an emergence of 'prosumers'. The term prosumer refers to energy consumers who also produce their own power from a range of different onsite generators (IEA-RETD, 2014). This means that consumers are becoming more recognised as players in the energy system giving them more responsibility.

3 The future development of the electricity system

3.1 Scale of Electricity Generation

Decentralisation can have different meanings depending upon countries, languages and fields of research (Finney et al., 2012). Within the current energy policy literature, a range of terms that encompass the ideas surrounding decentralisation are often used. These include ‘distributed’ and ‘embedded’ generation, which discuss the plant’s connection to the grid (Jenkins et al., 2000; Ackermann et al., 2001; Gumerman et al., 2003; El-Khattam W. & Salama, 2004; Pepermans et al., 2005; King, 2006; Lopes et al., 2007; Karger and Hennings 2009). The term ‘microgeneration’ is also often used in Government documents to examine small-scale installations (DTI, 2007a; 2007b; DECC, 2010a; 2011a). This thesis will use the different classifications and terminology in order to establish a well rounded definition of a decentralised electricity system.

Each stakeholder may have differing approaches to decentralisation but one defining characteristic is reducing the distance from generation plant to the end user, providing a reduced overall transmission in comparison to a centralised model (GOfS, 2008). An additional dimension often combines decentralisation with low carbon or renewable characteristics (Purchala, 2006). However, for the purpose of this thesis decentralisation is not immediately linked with renewable generation, although it may provide access to some additional forms of low carbon technologies.

One aspect consistent with many of the definitions of a decentralised electricity system (whether they are from Government documents or academic papers) is their concentration on the technical aspects of generation. For this thesis, decentralisation is considered to be far more complex than just introducing the capacity of small-scale technologies. In a decentralised electricity system the technological and the social aspect would need to be considered. This would also include the change to industry, markets and consumers as well as considering the overall operation of the electricity system.

3.2 The future of the UK electricity system

The UK electricity system is constantly evolving, whether this is from external impacts on the system or from the drive by new developments and innovations in the supply and demand of electricity. The main developments for the electricity system impacting the demand for electricity include: a greater inclusion of electrified heat, electrification of transport, increased demand side response and greater levels of electricity storage. This section discusses this in terms of future demand, supply and network development.

3.2.1 Demand for Electricity

3.2.1.1 Electrification of Heat

A large proportion of the UK's demand for energy is for heat at 46% in 2011 across all sectors (DECC, 2012p). The majority of heat is produced from fossil fuels, with gas heating approximately 81% of homes and 52% for industry (DECC, 2012p see Figure 3-2 and Figure 3-3). The result of this is that the consumers' energy bills are closely linked to gas prices and therefore susceptible to the volatile changes to the price of gas and oil. One obvious way to reduce emissions is through the increase in efficiency in the home, businesses and industry which would reduce demand and by extension lower emissions. A second way is to transfer households from using gas for space and water heating to electricity. Similarly for transport to transfer the use of fossil fuels in cars, to electricity. If the electricity is from low carbon sources then overall emissions fall. It should be noted that this means of reducing carbon, takes little notice of the practicalities of customer preference or behaviour, or the possibility of introducing so much investment in electricity plants.

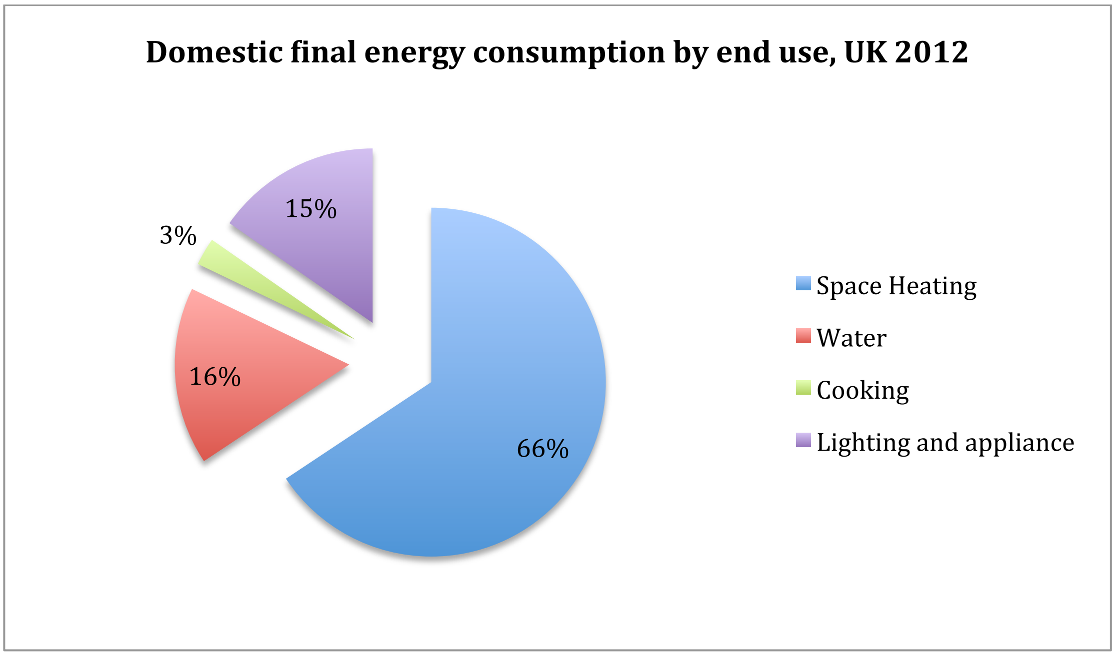

Figure 3-1 Domestic final energy consumption by end use, UK 2012 (DECC, 2013e)

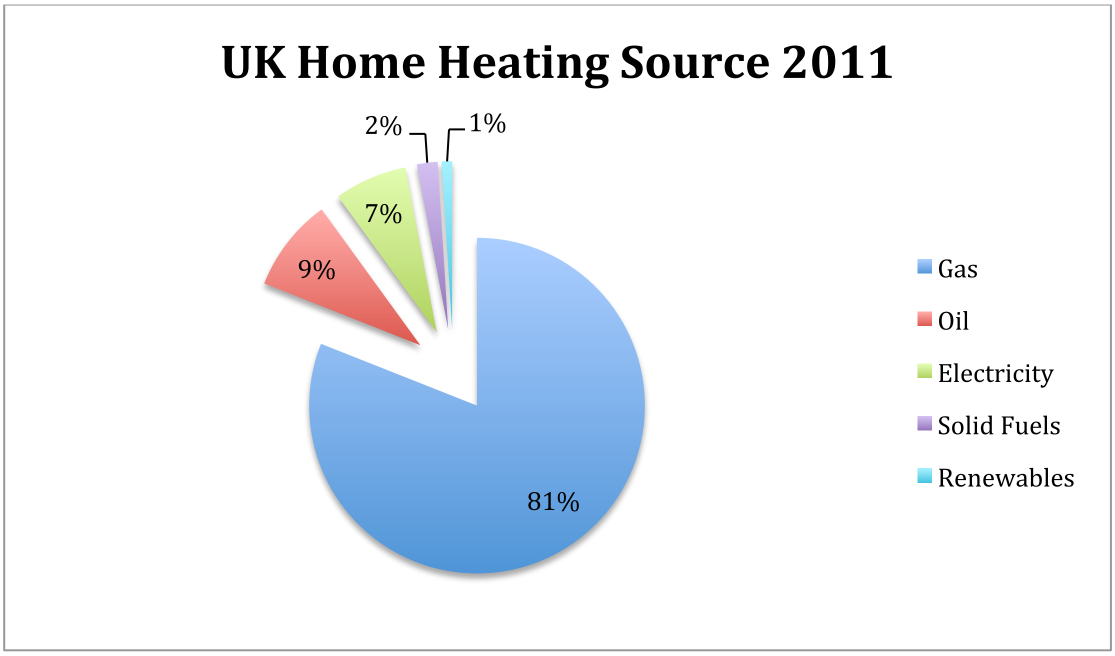

Figure 3-2 UK energy source for heating of homes (DECC, 2012p)

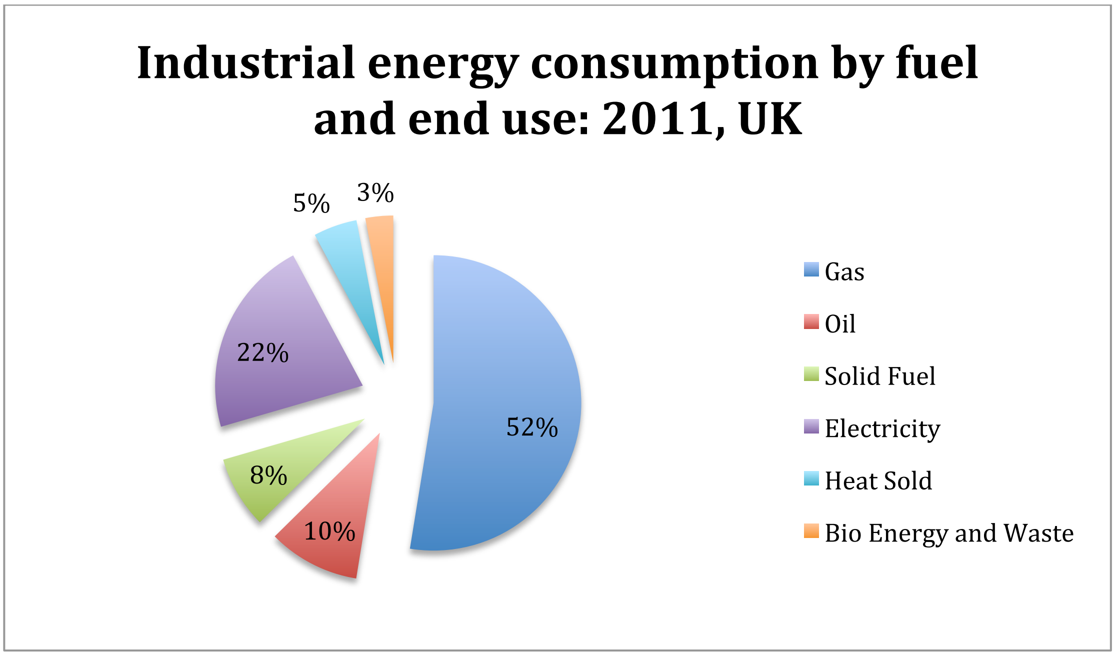

Figure 3-3 UK energy source for industrial heating16 17(DECC, 2012c)

In order to meet UK Government's targets of reducing carbon emissions, the Government have produced 'roadmaps' to identify how this can be achieved by 2050 (DECC, 2010d), Speirs et al., 2011). The 'roadmaps' provide a set of scenarios to meet a carbon reduction of 80% by 2050 from 1990 levels. Each of the scenarios show a future where electricity demand not only increases but also takes on a larger share of overall energy consumption, including the possibility of an all-electric future. At present, 7% of households already use electricity for space heating so increasing this to 100% would be a significant challenge. Moreover, the move to an all-electric future provides challenges to the electricity system's operational structure because there would be drastic changes to power flows and peak demands putting greater strain on the networks for delivery. Figure 3-4 shows the difference in the annual heat demand profile in comparison to the electricity demand showing the drastic change the electrification heat will bring to

16 Industrial heating includes: Space heating, high temperature process, Low temperature process and drying/separation

17 Heat sold is heat that is produced and sold under a contract (including CHP plants and community heating schemes) (DECC, 2011c) the overall electricity demand profile.

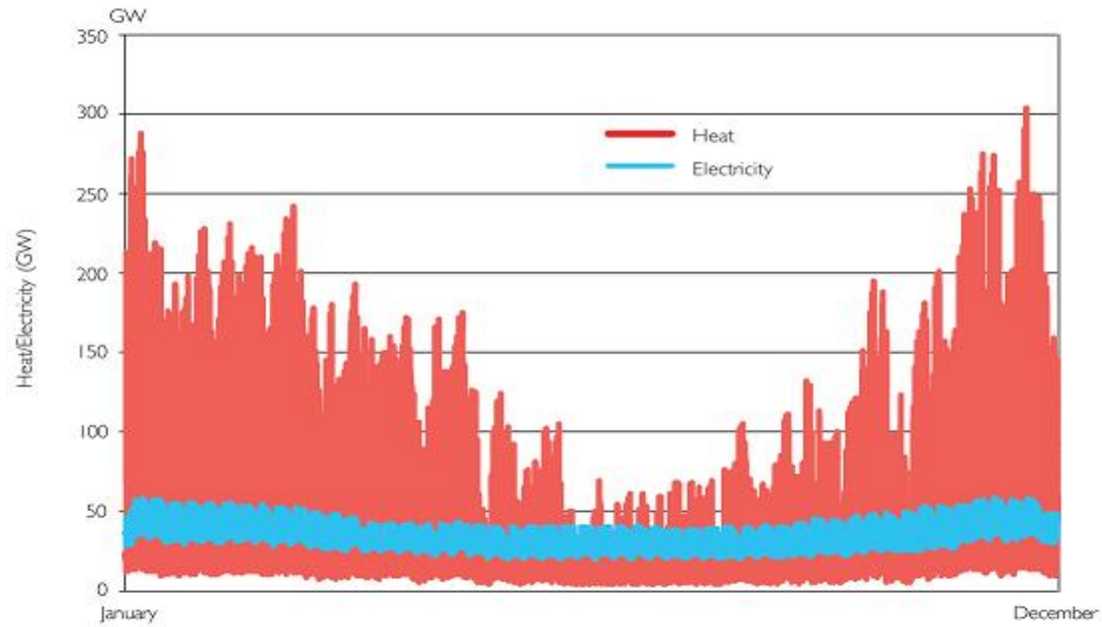

Figure 3-4 Comparison of heat and electricity demand variability across a year (domestic and commercial) (DECC, 2012p)

A further issue is the current reliance on fossil fuels at the power station level. If the reliance on fossil fuels continues, then the electricity system will be increasingly exposed to the global changes in fossil fuel prices. Figure 3-5 shows the price of selected fuel components and their trends. It identifies a greater volatility over the last decade compared to previous data. It can be argued that investors in the electricity system are less sure of their future operating costs and this will therefore increase their sense of risk and may lead to a reduced investment (IEA, 2007).

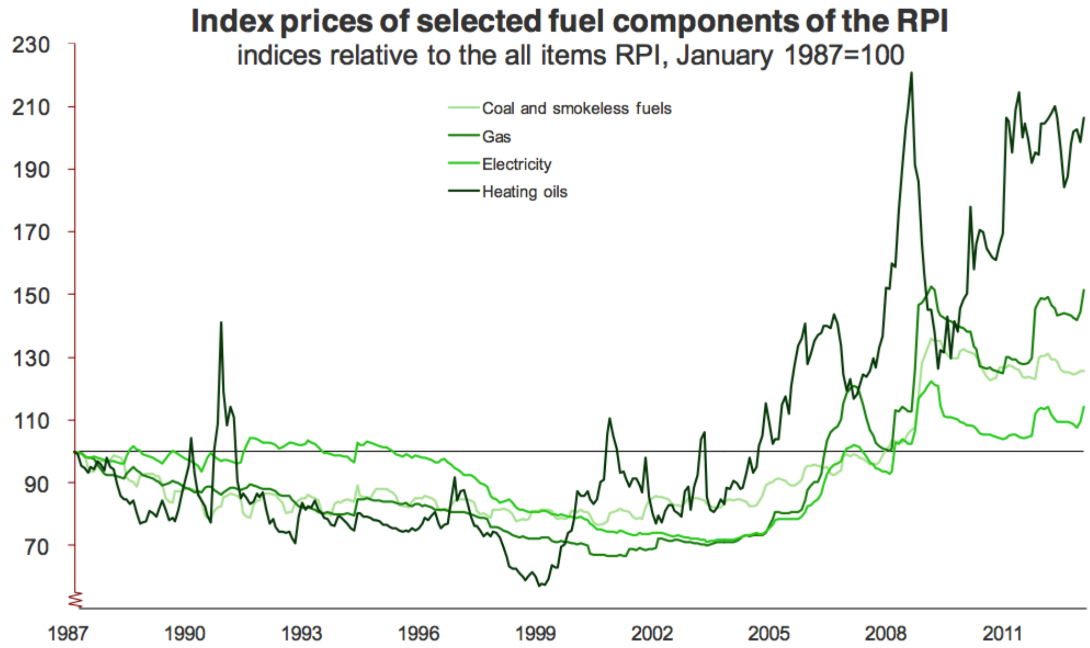

Figure 3-5 Index price of fuel identifying greater levels of volatility over the last few years (Bolton, 2013)

3.2.1.2 Electrification of Transport

As with the heating sector, the transport sector also offers a means to reduce carbon emissions through electrification. Domestic transport accounts for roughly 21% of the UKs carbon emissions (DECC, 2010d). Apart from electrification the emissions from transport could be reduced by improvements in fuel efficiency and an uptake in biofuels.

The modes of transport include public transport such as rail and buses, and private vehicles. The promotion of electric vehicles will generate an increased level of demand on the electricity network (Nat Grid, 2011). The electricity demand profile generated by the heating sector would be somewhat predictable, i.e. winter/summer changes, whereas daily routines with transport usage are likely to remain the same (Nat Grid, 2011).

As with the electrification of heat, the fundamental aspects of the electrification of transport in helping to reduce carbon emissions is, firstly providing a low carbon source of electricity. Secondly, that the low carbon sources of electricity are flexible and able to adapt to less predictable demand profiles.

3.2.1.3 Demand Side Response

Demand side response (DSR) focuses on changing the time of demand or use of electricity. It has the potential to enable greater efficiency in the network and the supply of electricity (Frontier Economics, 2012). It could remove the need for certain investment in generation capacity, networks and reduce the operating hours of less efficient generation plants (Bradley et al., 2013). The value of DSR in the electricity system will increase as the level and type of demand increases, especially with the introduction of electric heat and transport. The latter, if unchecked and without DSR, will increase not only the demand, but also the daily peaks of the system. DSR provides the ability to smooth this demand thereby reducing the need for extra generating capacity. In addition to this, DSR provides a greater level of flexibility to the electricity system, helping with the operation of less predictable forms of low carbon generation (Frontier Economics, 2012).

Some demand side response mechanisms have existed in the UK for a few years in the industrial and commercial energy sectors through interruptible contracts (Torriti et al., 2010). Interruptible contracts are agreements with the System Operator in which the consumers get a reduction in the levies charged to use the system or a reduction in the overall energy bill for limiting the amount of energy they use when the capacity margins are tight (Ofgem, 2010e).

A further mechanism is the multi-rate tariff, there are estimated to be 4.5 million users in the UK on multi-rate tariffs such as Economy 7 (Torriti et al., 2010). Multi rate tariffs work by offering the consumer cheaper electricity at night but more expensive rates during the day (in comparison to a standard tariff) (Ofgem, 2010e). This encourages consumers to use less daytime peak demand and use electricity during the night-time troughs in consumption.

An additional mechanism which has the ability to utilise the demand side as a way to help balance the electricity system is the use of time of day pricing. Time of day pricing is a strategy where by the electricity utility company changes the price of electricity supplied to the consumer depending on the time of day. By increasing the price of electricity at times when demand on the network is high, customers can be 'discouraged' from consuming thereby helping with balancing the electricity network.

DSR trials have begun around the world such as the Energy Demand Research Project (EDRP) in Great Britain which ran from 2007 to 2010 and included 60,000 different households (AECOM, 2011); the Ireland Electricity Smart Metering which 5,000 Irish homes and businesses participated in; and many trials in North

America (Frontier Economics, 2012). DECC commissioned Frontier Economics and Sustainability First to present the findings from 30 different household trials. The evidence shows consumers do shift demand in response to economic incentives. Automated responses on appliances which have flexible loads can be achieved through the energy tariff. Such as the long running Economy 7 scheme in the UK where the shifting of demand from day to night is achieved (Ofgem, 2012e).

The potential to change demand patterns to achieve the goals of the UK energy system is an unfamiliar concept to consumers. Electricity is viewed as a commodity to be consumed as and when it is wanted rather than having any restrictions placed upon its use (McKenna et al., 2011; Darby & McKenna, 2012). The report by Frontier Economics show the demand response working well with an automated operation and a lower response from the time of day pricing for consumers where the consumers have to act directly. This would suggest that either the pricing structure is inadequate, or the consumers need to be engaged more with the energy system operation. By engaging the consumers with the energy system, a greater level of understanding of the benefits and impacts of changing demand and even a sense of moral obligation can be achieved (Owens & Driffill 2008; Devine-Wright & Devine-Wright, 2004, Bovens et al., 2013)

3.2.1.4 Electricity Storage

The move to increased electrification of heat and transport coupled with an increase in variable low carbon generation are likely to cause greater difficulties in the balancing of demand and supply, through the volatility inherent in both aspects (DECC, 2012n). Current demand and generation profiles are shown in Figure 3-6. A potential 2050 model is shown in Figure 3-7 where the balancing of demand and supply is far more complex. Electricity storage allows the electricity which has been generated to be deployed at a later date, which could offer another way of meeting the concerns about balancing supply and demand

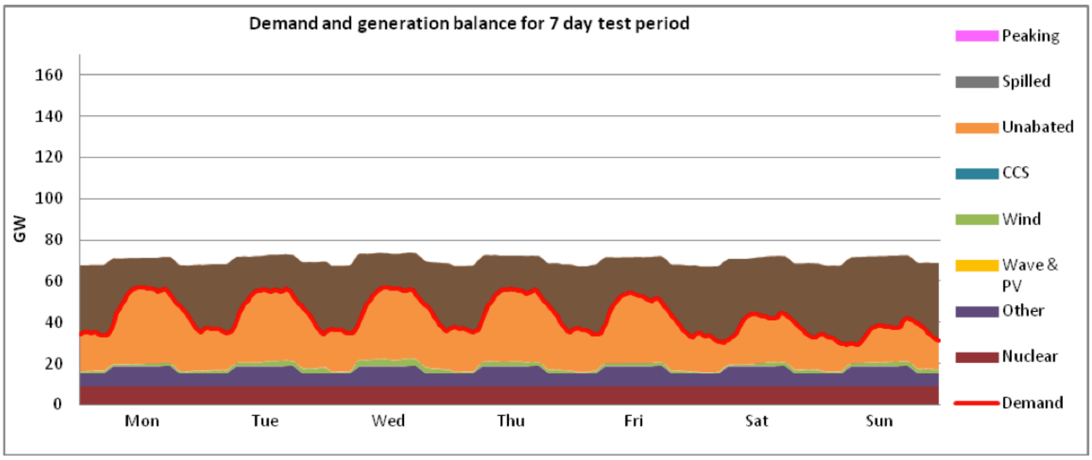

Figure 3-6 Current demand profile (red line) and generation mix over seven days on an average winter. (DECC 2012r)

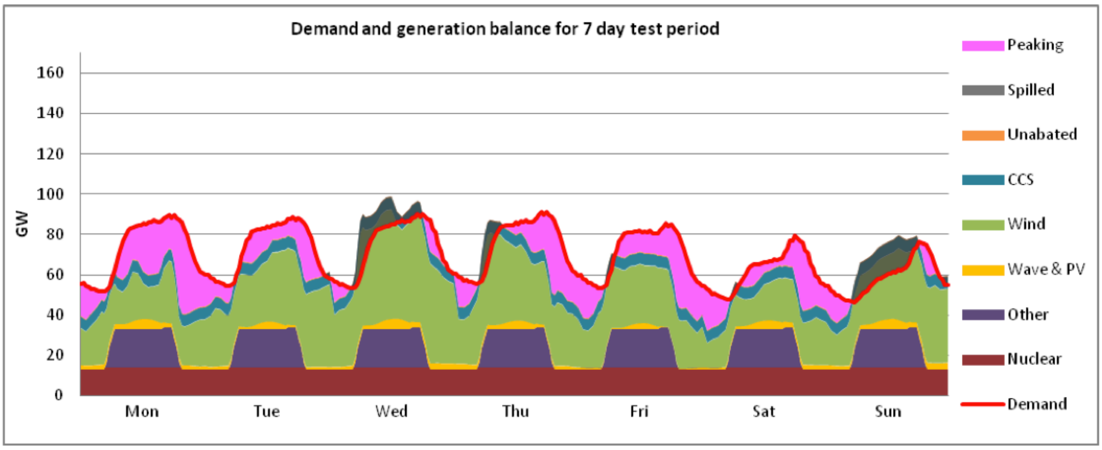

Figure 3-7 Potential 2050 demand profile (red line) and generation mix over seven days on an average winter. (DECC 2012r)

There are a wide variety of technological methods of 'storing' energy as a method for managing the power supply of a network. These can be divided into different categories such as: solid-state batteries, flow batteries, flywheels, compressed air storage, hydrogen, Superconducting Magnet Energy Storage, Super Capacitors and pumped hydro power. The different technologies have differing advantages and disadvantages including their size and their discharge time for their rated power, for further information see the ARUP guide to electricity storage (ARUP, 2013).

The UK Power Networks who are demonstrating storage technologies identify a set of stakeholder benefits for storage (UK Power Networks, 2013).

- An alternative to traditional reinforcement.
- Reduces peak demand, reducing losses and improving asset utilisation.
- Cost effective balancing support to the electricity system.

- Saving in Carbon Dioxide emissions from displaced peak generation, estimated to be around 1.7k tonnes of CO2.
- Validation of the business models and economics of storage when leveraged for full system value, resulting in building experience and encouraging adoption on a wider-scale.
- Support the development of the commercial environment for ESCOs, developers and investors.
- Identification of the key market, commercial and regulatory barriers to effective deployment

Storage has the ability to smooth supply profiles from variable, less predictable sources and can be deployed at times of high demand. This offers significant balancing services and can reduce the use of high carbon, less efficient power plants. Storage systems also have the ability to remove the need for investment into networks, which would be required to meet peak demand if the smoothing did not occur (DECC, 2012r).

3.2.2 Supply of Electricity

3.2.2.1 Ensuring Sufficient Investment in Electricity Generation

Over the last few decades the UK energy sector has been changing to incorporate market reform, liberalisation, privatisation and restructuring of the electricity sector. The privatisation of the electricity industry in the 1990s meant that it was up to the competitive markets to deliver the majority of the incentive for investment in a new generating capacity (Joskow, 2006). The design of the competitive markets was to open up the possible diversity of the electricity system and to keep the costs down. It is Ofgem's role to ensure that these markets are competitive and to monitor the end price of electricity for consumers in the retail market (Ofgem, 2012c).

The introduction of competition can make it difficult to identify who is responsible for ensuring energy security (Lieb-Dóczy et al., 2003). Under the old state-run regime it was clearly Government who had a responsibility to ensure energy security and meet the goals of the energy system as they owned and operated all the energy assets. In a privately owned energy system without stakeholder roles clearly specified, responsibility for energy security is less clear.

The responsibility for supply security could be placed on the energy companies. This is because it is the energy companies who own the assets and have the ability to ensure sufficient capacity levels. However, in order to keep costs as low as possible the energy companies would want to keep the excess capacity margins as low as they can. Minimising electricity system capacity is beneficial economically as long as security of supply is achieved (Lieb-Dóczy et al., 2003).

3.2.2.2 Transitional Fuels

The future of the electricity system is likely to cause a range of capacity concerns from the move to a low carbon future. These concerns include the long lead times for new nuclear power plants with fears over a short fall in capacity which will occur after EU directives along with the end of certain power plants' lifetime. For the case of renewable generation there is a strong possibility that the variable nature of the technologies may cause difficulties at times of low output and high demand. However, the issues with renewable generation will likely be solved through the development of storage technologies and an active smart network operation (Grünewald, 2012; Strbac, 2012; DECC and Ofgem, 2014).

Therefore, the transition to a 100% low carbon future would require a technology which is able to be flexible and meet the multidimensional demands of moving to a low carbon electricity system. One such technology that is widely considered as a 'bridging fuel' to a low carbon system, is the combined cycle gas turbine (CCGT) (IPCC, 2007; IEA; 2011; Stephenson et al., 2012). The reasons for the use of CCGT is that it is a relatively inexpensive technology, which produces less carbon emissions relative to other fossil fuels. It has short lead times for construction and it can be used to follow demand patterns relatively easily.

However, the issues with natural gas is that it is still a fossil fuel, emitting carbon, therefore without carbon capture and storage technologies, gas will not have a role to play in the long-term low carbon future other than acting as a back up technology.

3.2.3 Networks

Electricity supply and its security hinges on an efficient electricity network. The networks are the physical link delivering electricity from the generation plant to the consumer. The future changes to the electricity system, such as the expansion of low carbon technologies, increased demand response and storage, and then possible increase in overall electricity demand will require networks which can cope and adapt to these changes (Frontier Economics, 2009; DECC, 2012r).

3.2.3.1 Smart Grids

One-way to achieve these changes is for the networks to be fitted with greater levels of information and communication technology, resulting in a 'smarter' grid (Clastres, 2011). Greater communication and information will give the network operators a better understanding of the variations in supply and demand by time and place so that the network can be run in a more efficient and dynamic way (DECC, 2012k).

In order to start the move to a 'smarter' network the Government has introduced a policy to ensure that by 2020 all homes will have smart energy meters. These will provide real time information (if the customer takes notice of them). Thereby enabling the consumer to reduce and change their demand behaviour (DECC, 2011g). Ofgem has provided £500m from 2010 to 2015 as a part of the Low Carbon Networks Fund specifically for the Distributed Network Operators to trial new technologies and operational procedures (Ofgem, 2012f). In addition to this the Government and Ofgem have set up the 'Smart Grids Forum' which is intended to identify how the electricity network companies will operate in a low carbon future (DECC and Ofgem, 2014).

3.2.3.2 Interconnection with Europe

The UK electricity system currently have very little connection with Europe and other market systems (Ofgem, 2010f). It amounts to 4GW of interconnector capacity. There are four connections linking GB to France (IFA), Northern Ireland (Moyle), the Netherlands (BritNed) and the Republic of Ireland (East West) (see Figure 3-8) (SSE, 2011a; DECC and Ofgem, 2012; National Grid, 2013). Figure 3-8 also shows three potential future interconnector opportunities to Norway, Belgium and a second to France. The interconnectors in place today are indirectly operated and not associated with the UK transmission business (Ofgem, 2010f; 2014c).

The advantage of increasing the level of interconnectivity is that it increases the available capacity, including the back-up support portfolio for the UK. It gives the possibility of providing an uninterrupted supply of electricity for consumers (Parliamentary Office of Science and Technology, 2001) as long as the electricity is available for export from the exporting country (SSE, 2011a). The advantages of linking to other markets are firstly, that during a shortage of supply the interconnectors can provide another source of electricity therefore improving balancing services, secondly, mitigating the impacts of possible future variable generation and thirdly an increase in competition from European markets (ECC, 2010).

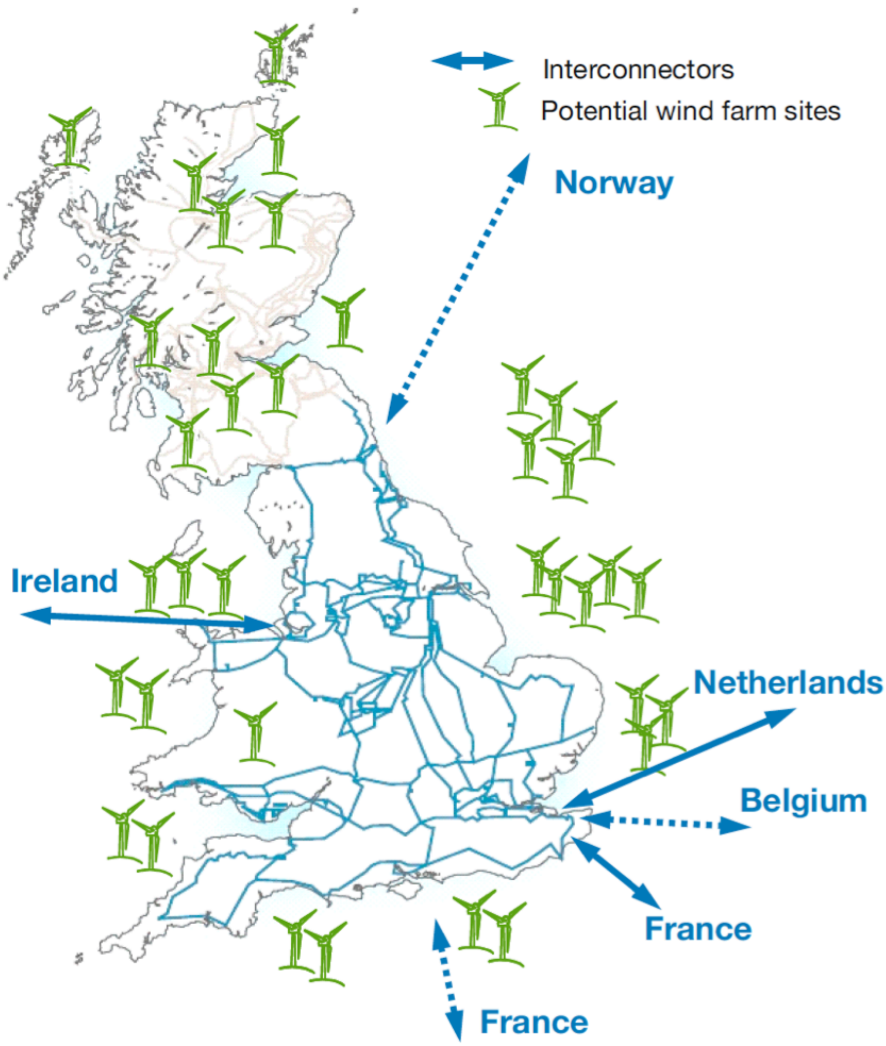

Figure 3-8 UK's interconnection with Europe (National Grid, 2013)

3.2.4 Geopolitical Influences

The interconnection with Europe involves the electricity system in a physical link to other countries and the policies with which they operate. In addition to this the primary resources utilised in current electricity generation are unevenly distributed around the world, specifically fossil fuels. These resources are often linked directly to a country's economic development. Therefore, a country that does not posses sufficient resources would be exposed to the global markets and may be vulnerable to supply interruption (Skea and Ekins, 2014).

The complexity associated with the geopolitical influences means that this thesis will not be able to enter into a detailed discussion. Geopolitics of energy focuses on understanding both the geographic resources and the political relations of their accountability. This thesis does not focus on the geopolitical aspect of security of supply.

3.3 Summary

The external impacts on the energy system means that the structure and operation of the UK electricity industry needs to change. Arguably the greatest challenge to the energy industry is climate change. Energy use and transportation of energy contributes 63% of the overall carbon emissions (DECC, 2013a). Following this the Government has placed targets on the energy sector carbon reductions: 80% reduction by 2050 from 1990 levels. There are also shorter term targets to meet the Carbon Budgets (DECC, 2009b & 2011i).

In order to meet these targets large amounts of investment will be required in a time of economic difficulty and when many of the current power stations are coming to the end of their lifetime. Alongside the carbon reductions, the UK Government has identified additional goals which set the overarching context in which policies are established. These include ensuring energy security and the affordability to consumers.

Energy security, climate change, and affordability - each in their own right - provide a challenge to policy making in the energy sector. Together they provide a multi-faceted and complex situation with a range of possible policy answers. These challenges to energy policy also come at a time when additional changes to the energy system have been suggested, such as the electrification of heat and transport sectors. Although these suggestions may help with respect to eventually meeting carbon budgets, they provide a concern in the balancing of supply and demand.

So far the balancing of supply and demand is dominated by the supply side providing for the needs of the consumer. The future may see changes to this through the development of more demand side response, which could help with many of the Government's policy goals. This, coupled with the development of new storage opportunities, could reduce the difficulties of balancing greater electricity demand while having greater levels of inflexible and variable generation.

On the other hand, increased links to other electricity markets and capacity may improve the security of the electricity system.

The future electricity system in place in 2050 will look very different to the current situation. The direction of change the system will take is not fixed, although, the Government is promoting large scale low carbon technologies over the smaller scale with the market reform package. This thesis looks at the changes a small-scale decentralised system will bring to energy security, including changes to operational procedures and structure. The concept of decentralisation has different meanings for different stakeholders. It can also include a range of different terms from 'distributed' to 'embedded' generation which each discuss the small-scale technologies. However, for the purpose of this thesis decentralisation will include not only the technological aspect of small-scale but also the change to industry, stakeholders, regulation and the market approach. This thesis is asking whether a decentralised approach to the electricity system is better placed to meet the goals set by the UK Government specifically around the implementation and governance of energy security.

4 Energy security in UK policy

The previous chapter looked at the development of the electricity system since the 1990s. This chapter will be more specific in identifying the development of understanding of energy security within UK Government policy. It will then categorise the various dimensions of security for the electricity system, looking at the drivers, issues, risks and impacts each of which lead to the system requirements for a secure system which provide the definition for security to be used in this thesis.

4.1 Evolution In Government Policy

The development of the governance of energy security over the last few decades can provide insight into the current situation and how governance might develop in the future. The energy system has historically met challenges to security, such as its over-reliance on a single fuel (for example, coal in the 1940s and the growing dominance of gas in the 1990s) (Helm, 2002; Brown et al., 2008; Cherp and Jewell, 2011). In addition, fossil fuels in particular can be vulnerable to the dominance of international groups such as OPEC who have the ability to control the price of oil (Lefèvre, 2010). Other threats have included domestic activism such as the coal miners' strikes in the 1980s and the fuel blockades in 2000 (Polak et al., 2001; Watson and Scott, 2009). More recently, concerns around capacity levels have arisen due to the planned closure of nuclear power plants and the introduction of European policy requiring the closure of carbon intensive plants (LCPD and IED) (Ofgem, 2012h). Each of these has the potential to threaten the energy system and its supply chains.

4.1.1 The development of policy for energy security

Until recently, there were no specific policies designed around ensuring energy security beyond its use in broad policy statements which identified that energy security was a concern and should be a central policy interest and the use of NETA and BETTA to ensure security of supply (Parliamentary Office of Science and Technology, 2012).

Much of the policy debate about energy security is based on the Government's understanding of it as an issue of supply, rather than a wider approach to energy security. Supply security is an important aspect of energy security, looking primarily at ensuring the lights stay on in the short-term. However, energy security in this thesis encompasses the short, medium and long-term aspect of the electricity system and is therefore a broader approach than the dominant political understanding.

This thesis will start with the New Labour Government's first energy report through the Department of Trade and Industry (DTI) in 1997 which set out the Government's central objective for energy policy which was to, "*ensure a secure, diverse and sustainable supply of energy at competitive prices*" (DTI, 1997 Pg, 3, in Rutledge, 2007). In this report a distinction was made between 'short', 'medium' and 'long-term' energy security, however, the 'longer term' issue was deemed to be *"..beyond the scope of the chapter"* and therefore, of no concern to the Minister at this time (DTI, 1997 in Rutledge, 2007).

Following this, the Government issued the 1998 White Paper: 'Conclusions of the Review of Energy Sources for Power Generation' (DTI, 1998). One of the main outcomes of this was the inclusion of a constraint on the permitted running hours for gas-fired generation on the basis that the continuing growth of gas generation could mean that it would eventually dominate the system to the extent that it could distort the market and inhibit the integration of other technologies, so reducing diversity (DTI, 1998; PMSU, 2001). This was based on the concern that in the non-interventionist, market-based electricity system a single resource, generating electricity at a much lower cost in comparison to other technologies would dominate the system and that relying on a single fuel source was risky. This was the beginning of the UK debate about the importance of security as a factor in the energy system. This will be discussed further in section 4.2.4.2.

The growing alarm over the rise in price increased the awareness of the UK energy system being reliant on natural gas. In 2001, the DTI and Ofgem set up the Joint Energy Security of Supply (JESS) working group with the aim of monitoring security of energy supply on a regular basis (Rutledge, 2007). It consisted of members from DTI and Ofgem and was attended by other representatives depending on requirements of discussion by members of the PIU at the Treasury, The Scottish Executive, National Grid Transco, and the Foreign Office (Wright, 2005; HofC, 2007). Its role was to:

- Assess the available data relevant to security of supply, to identify the gaps in that data and develop appropriate indicators
- To monitor at a strategic level, over a timescale of at least seven years ahead:
    - The availability of supplies of gas
    - The availability of supplies of electricity and fuels used for electricity generation
    - The adequacy of generating capacity
    - The adequacy of the UK's gas and electricity infrastructure
- To assess whether appropriate market-based mechanisms are bringing forward timely investment to address any weaknesses in the supply chain that are anticipated
- To identify relevant policy issues and consider implications
- To report twice yearly to the Secretary of State and the Gas and Electricity Market Authority

(JESS, 2002; HofC, 2007)

The first JESS report published in 2002 provided a view of security since privatisation. It showed that there had been very little impact as a result of interruptions to supply, or widespread price increases as a result of supply shortages, network issues or inadequate balancing arrangements. The only supply security issues shown in the JESS report (2002) that occurred were short lived. These included weather related issues or a localised temporary interruption on the distribution side of the network, meaning that each issue would only affect a small number of customers. The role of JESS, however, was to monitor a set of 'security of supply' indicators and had no ability to intervene in policy decisions and regulatory changes. It ran until 2006 when it was replaced by the Energy Markets Outlook which also met the Government's and Ofgem's obligations under section 172 of the Energy Act 2004 (DECC, 2009d)

4.1.2 PIU Energy Review and the 2003 White Paper

In 1998 the Performance and Innovation Unit was set up to report on issues such as energy policy, waste, policy analysis and leadership in Government. The PIU model was that of a small unit which could 'drive' policies though the Cabinet departments (Flynn, 2007). In 2002, The PIU released the 'Energy Review' green paper. The PIU noted that use of natural gas would increase in both primary consumption and for electricity generation, while the UK would become increasingly dependent on imported oil and gas. However, the report argued that this was not a major area of concern as the liberalisation of the European gas markets would provide an added level of diversity to the UK's energy supply mix. The report also argued that the Government should continue not to intervene in the market, and instead it should monitor its operation and regulation, including implications for security. Where Government intervention does occur they need to ensure the risk levels associated with the intervention outweigh the impact of the imperfections in the market.

While the PIU argued for non-intervention in the market, the reality was somewhat different. In 2002, the share price of British Energy, the nuclear generator, collapsed and the company was effectively bankrupt. In theory, the collapse of British Energy could have removed around 20% of generation from the system. Instead of allowing the market to decide British Energy's fate, the Government intervened to re-nationalise the company on a temporary basis to own 65% of future cash flows, showing a clear case where the market-based system had failed (Rutledge, 2007).

The PIU Energy Review provided a basis for the Government's 2003 Energy White Paper. The aim of this was to put in place the policy framework to shift to a low carbon economy based on competitive markets, the Government would set up the framework for this to happen and once again monitor the energy system without getting involved. The Government set out four goals in the 2003 White Paper: the environment, sustainability, fuel poverty and energy supply reliability. The concept of 'energy supply reliability' had been adapted from the term 'energy security' from previous documents. This change in wording could be considered, according to Rutledge (2007), to provide the Government a backward-looking perspective. Therefore, to meet the goal of 'reliable supplies' of energy, a review of past events would be the only indicator of security. Energy security, however, requires a forward-looking approach to provide future reliability. The White Paper showed the new path of tough carbon emissions targets and it was this, which caught the most attention of the media. However, it also showed the importance of security of supply and the need to avoid over dependence on imported energy using diversity to reduce the UKs vulnerability to these threats. The terms for energy security used in the report were 'ensuring security of supply' or 'energy reliability' which does not indicate a complete overview of energy security as will be used in this thesis. The report also identified that regulation is required in order to deliver security. Therefore the Secretary of State and Ofgem both have duties to ensure that reasonable demands for electricity and gas are met (Wright, 2007). However, although it proposed investigations into providing incentives to invest in plant capacity and gas storage, it did not follow through these proposals with concrete action (Watson & Scott, 2009).

4.1.3 Security of Supply Report

The Security of Supply report is a joint document produced by DECC and Ofgem. The report is an obligation set by the 2004 Energy Act (section 172). Beginning in 2005, the annual report was to look at the short and long-term availability of electricity and gas, which meet the reasonable demands of consumers in Great Britain (Parliament, 2004). In addition to this it covers the Governments obligation under certain EU directives to monitor electricity and gas supply levels. This was then covered by the Energy Markets Outlook, which followed on from JESS (DECC, 2009d)

4.1.4 2006, Energy Review and the 2007 White Paper

After the 2003 White Paper came the 2006 Energy Review, in the wake of a fast changing period in the energy world. One of the major changes in from the 2003 to the 2007 energy white paper was the emphasis on carbon reduction. This illustrates the impact of stakeholder influence over political decisions, showing how Government policy documents can shift over a few years. However, it could also be argued that the 2007 White Paper was a way of bringing nuclear power back into discussion.

The White Paper set out two energy security challenges, the first was to manage the increase in dependence on oil and gas imports as North Sea reserves declined, the second was to ensure the market delivered the investment in electricity generation and networks in order to keep the cost of electricity 'affordable' (pg.10). To do this, the Energy Review set out a dual strategy of encouraging open competitive markets outside the UK, to allow UK energy companies to trade without the need for Government intervention, and to establishing a positive framework for domestic supply investment (DTI, 2006b).

The Energy Review therefore reinforced the Government's previous endorsement of using a market-based approach to ensuring the energy security requirements of the UK were met. Very little was changed in 2007 when the DTI published its White Paper 'Meeting The Energy Challenge'. Here the Government again identified energy security as one of the two main challenges facing UK energy policy (DTI, 2007a). Much of this was centred on the need for sufficient investment in order to address capacity concerns and estimated that around 30 – 35 GW of new generation capacity would be needed over the next two decades to replace existing stations which were soon to be retired (DTI, 2007a). For the first time, the White Paper recognised the issue of ensuring that companies would need reassurance about the return they would receive on their investment in liberalised energy markets and acknowledged that this was a potential problem in the context of ensuring the security of the UK's electricity system. (DTI, 2007a; Rutledge, 2007). In addition to this the paper highlighted the need to rethink the planning process, the reliance on imported fuel and the energy production methods. From this a consultation into the UK's nuclear power production began (Coaffee, 2008).

4.1.5 Electricity Market Reform

The most recent significant changes to the electricity system are through the Electricity Market Reform package. The specifics of the EMR have been discussed in section 2.2 of this thesis. The main actions of the reform around energy security is to incentivise greater investment into the electricity system. This would signify that the Government would remain in its hands-off role regarding energy security leaving the immediate responsibility to the energy companies and network operators. Having said this the EMR package through the Contracts for Differences and the Carbon Floor price effectively 'picks winners' for the future of the electricity system (Gross et al., 2012). The issue with this is that the markets do not perform in a predictable and reliable pattern. All the market players would need to be rational, responding to 100% accurate information about costs and benefit, thereby allowing resources to be allocated swiftly. With no political intrusion and because of so much change in the electricity system as a result of EMR, the electricity system is leading to a hiatus in investment until the future becomes clearer (Temperton, 2011).

4.1.6 Energy Security Strategy

4.1.6.1 What is the ESS

In November 2012 the UK Government published the Energy Security Strategy (ESS) (DECC 2012o). This was the first time the UK Government had set out any detailed analysis for ensuring energy security other than identifying it as a 'challenge' to the energy system[18] (DTI, 2003; 2007a). Together with the ESS, the Government and Ofgem published its first Statutory Security of Supply Report, a factual report on the ability of electricity and gas levels to meet the consumer demand (DECC & Ofgem, 2012). The Statutory Security of Supply Report is an obligatory report set out in the Energy Act 2004, Energy Act 2011 and under the EU Directives to monitor gas and electricity supplies (Directive 2009/73/EC), and is updated annually.

Three main drivers were identified for the publication of the ESS:

- The imminent closure of power stations (discussed in section 2.5.2)
- The decline in UK Continental Shelf reserves, and the resulting need to import more fossil fuels, particularly gas
- The need to encourage investment in low carbon technologies in order to meet the UK's legally binding carbon reduction targets

The closure of the power stations (identified in section 3.8.1) causing a reduction in capacity coupled with a possible increase in the level of demand (see section 2.3.1) could develop the very real possibility of an 'energy gap' (Gore and Ares, 2010). The second point identifies the economics of energy security as an important factor for ensuring security in a low carbon future.

The third and final point, indicates Government recognition of the future of fossil fuels as a risk to energy security, specifically if the energy system remained dependant on gas, oil and coal. The concern indicated by Government is toward the lack of self-sustainability, however, there is an argument to suggest that imports for the energy system could increase diversity of supply chains and therefore security (Mueller, 2014). Although, a more pressing issue associated with fossil fuels, is the current UK dependence on natural gas, making it a dominant influence on the end price of energy (Parliament, 2013). Since the price of fossil fuels can be

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18 In 2009 Malcolm Wicks carried out a review of international energy security and how it affected the UK energy security (Wicks, 2009) extremely volatile and future changes not easy to predict, meaning the end price of energy will also be uncertain.

The focus of the three challenges to energy security are firmly based in ensuring the capacity is there to meet projected demand, and that there is sufficient investment in infrastructure to enable its delivery, identifying energy security firmly as a supply issue. This is emphasised in the annual Statutory Security of Supply Reports, which focus almost entirely on supply side issues (DECC and Ofgem, 2013)[19].

Before the ESS the UK Government had not provided a definition of energy security. This issue was identified by the Energy and Climate Change Committee (ECCC) report "UK Energy Supply: Security or Independence?" (ECCC, 2011). The ECCC report argued that previous descriptions referred to the absence of interruptions to electricity, gas and petroleum products to end users. The Committee recommended that the Government adopt the following definition (p15):

> *… a secure energy system is one that is able to meet the needs of people and organisations for energy services such as heating, lighting, powering appliances and transportation, in a reliable and affordable way both now and in the future.*

The Government responses to the ECCC report implicitly acknowledged the need for a definition, and stated that (ECCC, 2011 pg. 1):

> *… energy security encompasses a variety of aspects, and there is no perfect definition. At its core is the concept of a reliable supply, that is there when needed. It also needs to include dimensions of price (volatility as well as absolute level) and sustainability.*

While the ESS does provide a definition, it is a somewhat simplified version of that responding to the ECCC report:

> *"ensuring that consumers have access to the energy services they need (physical security) at prices that avoid excessive volatility (price security)" (DECC 2012o pg. 5).*

The issue of sustainability has been removed from the core definition and is instead framed as something that must be delivered alongside energy security,

[19] *There is some discussion of future network development and demand side response measures, but this is very limited and deals only with established conventional approaches rather than new ones.*

rather than as an inherent part of it. Overall the definition does not move far from previous Government discussions with the exception of the addition of a price volatility element. It also stops short of explicit criteria such as a desirable level of capacity margins or adequate diversity against which the state of energy security could be judged.

The ESS therefore does not add much to the debate about how energy security might be assessed in absolute terms, but it does provide an interesting outline of how the Government approaches assessing risks to energy security. Essentially, the Government uses three approaches: horizon scanning for possible future threats, assessment of various characteristics of the energy system (capacity, diversity, reliability and demand side responsiveness), and finally stress testing. These assessments are intended to identify threats to the existing in the short (up to 5 years), medium (mid 2030s) and long-term (up to 2050). However, the emphasis of the approach is on the existing system, and identifiable threats relating to it; it is not directed at considering how the system might change, for example by increasing levels of decentralised generation, and what positive or negative implications this might have for future security. As with other, broader energy policy statements, the ESS starts from the position that the market will be used to address the majority of the challenges to energy security. However, it acknowledges that the way that the market values the risks to energy security does not necessarily correspond to the way that the Government would value those risks, meaning that the security provided by the market alone might not be socially or politically optimal. In the face of this possible market failure, Government interventions might be necessary to ensure energy security.

These further actions include more effective regulation and establishing a capacity market to ensure that there is an adequate capacity margin in electricity generation (see section 3.5.2). This means there is a very open ended concept of how the governance of energy security will be handled: by relying primarily on the market, the Government is taking a slightly hands off approach to energy security. The responsibility for this will then be placed on Ofgem to ensure the electricity market and associated measures provide sufficient security. However, it also provides an opportunity for Government to intervene to address perceived market failures in the future, but the level of intervention is left undefined.

Robinson (2013) has criticised the ESS saying that if the Government were to promote the market system then it needs to separate itself from its operation. He argues that Government action is assumed to be perfect, whereas this is not always the case and perhaps the markets without Government intervention would be better off. This is also identified by Mueller (2014) who argues that markets are far more stable than the alternative, being Government policies, which are adapted and changed as Governments change. These arguments come back to the issues identified earlier in this thesis: the relationship between a market led approach to meeting energy policy goals, including energy security, and broader governance issues needed to address market failures.

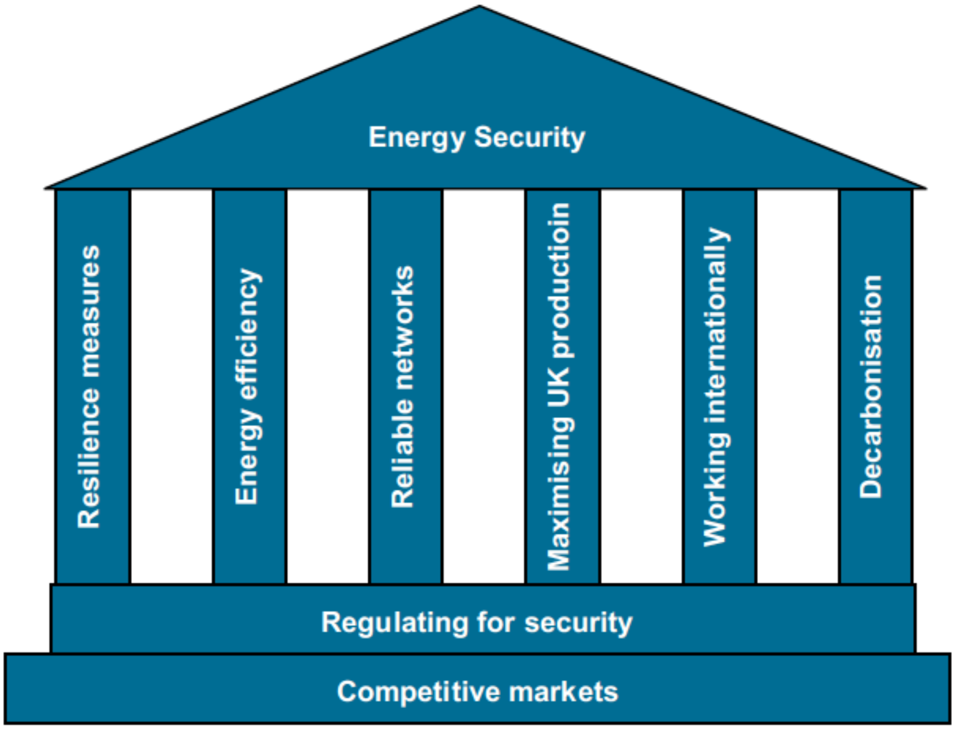

Figure 4-1 UK Government Policy areas contributing to energy security

The ESS identifies competitive markets and selective intervention as the foundations for delivering energy security, and it sets out six policy 'pillars' which also contribute (Figure 4-1). These are:

- Resilience measures to protect against and prevent short-term disruptions such as flooding and industrial action (e.g. emergency plants, stockpiling of oil). These are short-term, reactive measures which do not seek to address broader systemic issues in the longer term
- Energy efficiency to lower the exposure to price risks. The ESS has very limited discussion of the possible contribution of energy efficiency

measures to energy security, and instead refers to the Government's Energy Efficiency Strategy (DECC 2012w).

- Maximising domestic oil and gas to reduce exposure to international supply risks in the short-term. Improving the reliability of the global energy markets and providing the UK with a dependable and affordable source of foreign fuel in the longer term.

Ensuring reliable networks through expanding and upgrading transmission networks, developing smart grids and increasing interconnections. The focus of this pillar is predominantly on transmission networks, and there is little discussion of the requirement for DNO development. The primary discussion for the DNOs is that they need to:

> *"meet increasing electricity demands and to connect new low carbon technologies, such as electric vehicles and heat-pumps, and distributed generation, such as solar photovoltaic panels." (DECC, 2012o pg:42)*

However, the development of a DNO becoming active and acting as system operators for their individual networks would have indicated a serious opportunity for promoting a large level of decentralised electricity generation. The absence of this discussion indicates that the Government only identifies the centralised approach as viable for energy security.

Decarbonising supplies to reduce emissions and reducing dependence on international fossil fuel markets. This is obviously coupled with the third and fourth aspects (focusing on the production of domestic oil and gas and improving the reliability of the global energy markets respectively).

The policy pillars raise some key issues which are worth highlighting. Firstly, the narrow, supply based approach to energy security means that the ESS fails to relate ensuring energy security to wider Government goals of affordability for both private consumers and business and also climate change (Hoggett, 2014). The document has a distinct lack of social accountability and focuses purely on the goal of ensuring security of supply.

Secondly, while the ESS identifies the need for long and short-term goals in energy security, this is not apparent in its approach which focuses on the short to medium term issues, particularly relating to fossil fuel supplies. For a longer term approach Government would need to discuss the benefits of flexibility in the energy system. A flexible energy system has the ability to change to any future changes, impacts or risks which may arise. This future flexibility means that measures may need to be taken now that conflict with the price security to ensure future issues can be met.

This leads to the third issue to highlight: the lack of appreciation that decentralised energy could play an increasing role in future energy systems, particularly electricity.

The ESS provides a limited discussion on the impacts of a small-scale decentralised energy system. The connection made is that small-scale energy technologies can help with the "decarbonising of our supplies" (pg.: 23) through the feed in tariff.

However there is very little discussion of how this will happen other than through RIIO-ED1 price control. The main issue here is that there is no recognition of small-scale electricity generation's ability to promote energy security.

Instead, the continued reliance on market arrangements which promote centralised technologies and the lack of discussion over decentralisation both signal that Government intends to continue to follow a traditional, centralised pathway. Overall, the ESS is a useful document in that it sets out for the first time what the Government's thinking on energy security is, but as a strategy it fails in the sense that it does not take a long-term strategic view of how the electricity system might develop in future, or indeed value the contribution that decentralised generation may or may not make to meeting the goal of energy security.

4.2 Defining Energy Security

While the focus of policy surrounding energy security has largely been on the fuel supply dimension of energy security, it is apparent from wider evidence that the concept of energy security should be broader than that. Energy Security is a multi-faceted concept, where different ideas of how the energy system does and should operate could provide different ideas for energy security. Therefore, for the purpose of defining energy security for this thesis, this section will discuss various dimensions associated with energy security beyond the simple fuel supply approach (see Figure 4-2).

This section will outline some of the key components and use them to develop a comprehensive definition of energy security. This definition will include both quantitative and qualitative factors which need to be considered when designing future governance arrangements intended to deliver a secure electricity system in the context of other policy goals.

One of the issues with many of the definitions of energy security is that they have a very narrow focus, emphasising the short-term security of supply aspect. However, this thesis will use a more comprehensive overview of energy security, establishing initially the: drivers, issues, risks or threats, impacts and then finally, the requirements of the electricity system to overcome these issues. by structuring the analysis of energy security in this way a breakdown of the effects and associations of energy security can be made and a full analysis of energy security achieved. The result of this is shown in Figure 4-2 at the end of the section.

The 'Drivers' of the energy system provide the four main concepts, which move the energy system in a particular direction (e.g. continuing on centralised pathway or moving to a decentralised electricity system) (adapted from Foxon et al., 2005). These are categorised into (1) social, (2) economic, (3) innovation and (4) political. From these four conceptual sectors of the energy system we can begin to map, and attempt to explain the causal dimensions of energy insecurity.

The 'Issues' category shows how the energy system can be affected by various externalities such as the (1) environment, (2) governance patterns or (3) international influences (adapted from Hoggett et al., 2011 and IEA, 2002a). The 'Risks or Threats' to the energy system are the direct security concerns which literature and policy makers have indicated as being related to security (Kruyt et al., 2009; Stirling, 2009; Chester, 2010; Barret et al., 2010). These include (1) domestic activism or terrorism, (2) reliability of demand patterns, (3) investment in infrastructure, (4) technological failure and (5) resource availability. The 'Impact' theme covers the response the risks can have on the energy system, ranging from, (1) number of blackouts and brownouts, (2) diversity and dependency, (3) market stability and (4) the end price of energy for consumer and businesses. Finally the 'System Requirements' category covers the rules which the energy system would need to adhere to in order to provide a short-term and long-term secure arrangement.

4.2.1 Drivers of the Electricity System

Drivers of the electricity system contain four main areas –(1) social, (2) economic, (3) innovation and (4) political - which direct the electricity system down a particular pathway. These four conceptual sectors of the electricity system are used to begin to map and attempt to explain the various aspects of the electricity system relating to energy security.

4.2.1.1 Social Drivers

The domestic sector accounts for approximately 35% of electricity use in the UK (not including transport) (DECC, 2013g). Changes in behaviour in this area can be difficult to predict as they are made up of thousands of decisions every day (Parag & Darby, 2009) and inextricably linked to the energy landscape and the other drivers of the energy system.

One example of this is the environmental changes; social action groups attempt to put pressure on the Government to develop environmental policies. With enough action it may become within the Government's interest to follow the 'wants' of society (Kooiman, 1993). However, this is not always as clear as it seems as different sections of society may have differing views on issues such as the environment (Divine-Wright, 2005).

Fluctuations to the security of energy, whether it is an increase in short-term blackouts or changes in market price, will have a direct impact on society (EC, 2000). The result of this can cause social action to try to make a change. This can be seen in the fuel strikes, which occurred at the turn of the century bringing transport in the UK to a standstill (Polak et al., 2001). A more direct way in which society can impact on the energy system is through the planning system. Direct consultation with local people on planning issues implies the individual is given the ability to demonstrate how they feel their local area should develop. However, this is skewed as different regions would have dissimilar ideas (Divine-Wright, 2005) and it is not possible for a complete social profile to attend the meetings.

4.2.1.2 Economic Drivers

The economic drivers of the energy system encompass the national and global economic challenges, which can affect the energy system (EC, 2000). Changes to the economy can have a direct impact on the markets and in turn the end price of energy in a liberalised system (Ernst & Young, 2012). Also, the security of the energy system has a direct impact on the economy; higher energy prices can trigger higher domestic production costs causing a spiral effect, whereby a downturn in the economy will affect the security of the energy system negatively which in turn affects the economy negatively (CSIS, 2009; Labandeira and Manzano, 2012). As the UK's economy begins to recover, demands for energy are likely to increase (Wicks, 2009) and require a system that can adapt to this change.

In addition to this the low carbon future of the electricity system will require a substantial level of investment to maintain and secure, estimated at £200bn with £168bn for the generation industry leaving £32 billion of network investment (Ofgem, 2010a). This large level of investment means that in global economic uncertainty this task is far more difficult (DECC, 2012o).

It can be argued that with the right complementary innovation there could be a number of different pathways the electricity system could take to become low carbon. However, it is likely to develop along the pathway which is the most economically viable in the short-term (Ekins, 2009).

The importance of innovation is in securing the UK's electricity future, while also meeting other policy goals which rely primarily on developing technologies and operational systems. An example of this is the development of more active electricity networks, interacting with both the demand and supply sides (Jamasb and Pollitt, 2008). Most areas of the electricity industry will require innovation over the next few decades, in order to provide operational flexibility in a system which will incorporate more renewable and demand side technology. (Jamasb et al., 2006). As innovation can be argued to be driven either by society, policy or technology it has therefore been used in this thesis as a driver of the energy system (Grubb and Ulph, 2002).

4.2.1.3 Political Drivers

The political dimension is a major factor on the development of the electricity system. While direct command and control intervention has been rejected as an approach and the market substituted as the key driver of investment choice, the Government still has a vital, if less direct, control over system development through setting the framework for investment. Government policies have the ability to shape the development of the system and its operation, through, for example, encouraging the deployment of increased levels of renewable generating technologies. It can be argued that political parties may design or alter their policies in line with the impact it may have on their party's rating for upcoming elections, rather than looking beyond the five year period. An example of this is during the surge in oil prices during 2008 when proposals were floated for oil tax reductions. Another proposition was the introduction of taxes on the 'excessive profits' of large international oil companies to provide subsidies to low income families (Jansen & Seebregts, 2010).

The political dimension of energy system development is not just limited to policy making in the UK. It also includes the global political conditions such as the ability to find resources outside the UK, whether this is primary fuels such as gas oil and coal, or secondary materials such as rare earth metals for the production of solar cells, skills and knowledge, or investment.

4.2.2 Energy Security Issues

The 'Issues' category sets out how the energy system can be affected by various externalities which are not directly concerned with energy security but which provide the basis from which the risks develop. These issues are (1) planning, (2) environment, (3) governance, (4) international issues.

4.2.2.1 Planning

Planning covers two key concepts, firstly, strategic planning is needed in order to meet the goals of a secure energy system whilst also reducing carbon emissions. This is a matter of governance, ensuring the system is capable of changing its operational procedures. For instance, the facility for international electricity imports would be increased through more interconnectors with Europe. This interconnection would become more important whether we move to a system dominated by intermittent renewable generation, or for a system of inflexible nuclear power. The difficulty with planning is the need for capacity to match future energy demand, which is inevitably unpredictable. (Barrett et al., 2010).

The second aspect is a more localised issue of planning consent, where individuals can have a direct impact on the energy system. The planning system can negatively impact on investment into the energy system. Local opposition to new energy generation has been discussed in academia and through the media, whether they are fossil fuel power plants, which may help replace the older retiring power plant, the construction of a local renewable technology such as wind turbines, or of new transmission networks such as the on-going saga of the Beauly-Denny line in Scotland (Devine-Wright, 2004).

4.2.2.2 Environment

Environmental issues seem to influence either directly or indirectly nearly every dimension of the energy system and system security in some way or another. Its major pressure is through climate change. The transition to a low carbon energy system provides the UK with many complications, such as finding a replacement for a fossil fuel based generation. Climate change also has another interaction with energy security; the rise in sea level has the ability to cause disruption to coastal based power plants, and heightened hostility internationally for resource competition.

This dimension can also include natural disasters, which can cause damage to infrastructure one of the most notable cases of this is the Fukushima disaster in Japan. These impacts can be amplified by climate change effects but could also be entirely independent. The variety and complexity of the environmental connections to energy security make it very difficult to quantify. The full environmental issue can often be overlooked in favour of focussing on a few impacts and neglecting the rest (Barrett et al., 2010).

4.2.2.3 Governance

The governance of the energy system relates to the institutions, the rules and incentives used to run networks and markets, and the detailed energy policies that are implemented (Kooiman, 1993; Rhodes, 2007; Florini & Sovacool, 2009). This then orders the relationships between customers and energy companies; it impacts on the investment and the development of supply chain issues, such as R&D, skills and knowledge (Florini & Sovacool, 2009)

Energy security stakeholders range from the individual households, business, through to national Government. One concern is the level of power each stakeholder may or may not have. An example of this was during the California supply crisis (PMSU, 2001) where rolling brown-outs, blackouts and high wholesale prices (PIU, 2002) pointed out the fragility of new market structures and indicated the requirement for strong and clear governance operations.

The governance dimension of the energy system makes up a major part of this thesis and will be discussed in further detail in chapter 5.

4.2.2.4 International Issues

The UK is becoming increasingly dependent on energy imports, not only for resources but also economically (Toke, 2011b; Bolton, 2013). The impact of international companies, agencies, and states can therefore be a major concern for energy security. The energy economy is fragile enough that when conflict breaks out between two foreign countries, the price of energy for the UK increases, ultimately impacting on the price for the end user. An example of this is the Russia – Ukraine Dispute in 2009, which resulted in a drop in demand from consumers even though there was very little immediate direct impact on the price of energy (Macalister and Sparrow, 2009; IEA, 2007). Another international concern for the UK in particular is the ownership of much of the electricity system by transnational energy companies. The complication here is where the company's allegiances lie. If there are options over where companies such as RWE or E.ON could invest, between projects in the UK and their home state, then the UK system would find they will be competing with other countries for investment (BIS, 2012; Ward et al. 2012).

4.2.3 Dimensions of Risk

The risk dimension stems directly from the issues discussed above. The term 'risk' is often discussed in reference to investments, where any investor will evaluate the risk against the rewards on a particular investment. However, for this thesis a risk to energy security is identified as the cause of a particular impact which can stem from the one or more of issues discussed in section 4.2.2.

This section will identify the main risks to the energy system and categorise them into: (1) domestic activism or terrorism, (2) reliability of demand patterns, (3) investment in infrastructure, (4) technological failure, (5) resource availability.

These factors have been used as they encompass the main risks associated with the electricity system. They not only identify the short-term shocks, but also the longer term risks on an electricity system. They are also not specific to small-scale or centralised technologies.

4.2.3.1 Domestic activism or terrorism

This dimension of risk incorporates the human threats to the electricity system, it includes both domestic activism and terrorism, however, other than the human factor they are not considered to be related. Any conscious human threat, which is intended to have an impact on the energy system directly or indirectly, can be considered to be activism (Waston & Scott; 2009). This group of threats also includes acts of terrorism where key sections of infrastructure may be sabotaged. Critical infrastructure could include gas pipelines, LNG terminals, and nuclear power plants. One of the problems associated with the risks of human threats is that it is not easy to quantify or estimate the losses making it difficult to identify for policy makers the impact of such a risk (Woo, 2002).

Domestic activism, historically, could be considered to have provided some of the major known impacts on the energy system (Grubb et al., 2006). The 1980s UK coal miners' strikes exposed vulnerability not only in the energy system but also in the socio-political dependence on the energy system. This was a first hand insight into the Government's susceptibility for energy issues and forced the Government to take emergency measures and rethink its security strategy though the operation of the energy system and the Governments responsibility in the energy system (Ledger and Sallis, 1995). In late 2000 further impacts on the energy system occurred such as fuel blockades of the supply terminals (PMSU, 2001; PIU, 2002). The 10 day oil refinery blockade left motorists without fuel which in turn caused shops to run low on food and for hospitals to run minimal services (GOfS, 2008). These blockades helped to demonstrate the vulnerability of the UK's supply networks showing how a system of 'just in time' delivery which is a common aspect across the electricity and gas networks are vulnerable to 'attacks' (Helm, 2002). Other domestic activism examples are the environmental protests towards the building of new fossil fuel power plant such as the 2007 Greenpeace demonstrations at Kingsnorth Power Station in Kent (Evans and Lewis, 2009). There were short-term and long-term impacts of the Greenpeace demonstrations. In the short-term the Kingsnorth power station closed for a short period of time. In the longer term it provided a platform for discussions over the future use of coal for generating electricity and it identified the weakness of electricity generating stations to human attack.

4.2.3.2 Reliability of Demand patterns

This category includes the risks directly related to the consumption patterns at the business and household level. One of the primary factors of energy security is to ensure that capacity will meet demand (DECC, 2012o); therefore, the risk of demand rising or falling and the current inability to provide an automated dynamic demand system creates a viable threat to the energy system.

Consumer behaviour is becoming a key element to developing energy security with their capacity to transform where the energy comes from, the end-user consumption intensity, and when it is used (Frontier Economics, 2012). This response to energy security was demonstrated during 2009 with the Russia – Ukraine Gas dispute. Although there was little direct impact to the UK energy system, many customers reacted by decreasing their demand (IEA, 2007).

The existing models of consumer interaction favours passive consumption (JRC, 2013; Gangale et al., 2013) where the consumer has little interaction with the energy system by making no adjustment in daily behaviour and making bill payments though direct debit. However, a change in the drivers of the energy market may be able to motivate the end user to engage a response with secondary benefits (UKERC, 2009). These include the move towards other policy goals such as a reduction in carbon emissions, a reduction in fuel poverty as well as ensuring energy security.

In order to meet the environmental goals set by the Government, simply replacing the fossil fuel energy generation with low carbon supplies will have a large impact on the economics and resources of the energy system. However, in order to meet the carbon budgets it is likely that reduction on energy demand is required (DECC, 2009a).

4.2.3.3 Investment in infrastructure

In order to develop the future of the energy system as Government and contributors suggest, a significant level of investment will be required. This will also be needed to maintain the current infrastructure with a business as usual plan (Ofgem, 2010a). This investment is not simply the money required for the physical upgrades off the energy system, it is also the investment in skills required for its development (Barrett et al., 2010).

The required investment for the energy system up to 2020 has been placed in the hundreds of billions; £165bn (Ernst and Young, 2008), £200bn (Ofgem, 2010; AEP, 2010). Ofgem identify how this requirement for very high levels of investment will prove difficult with the level of uncertainty which surrounds low carbon technologies (Ofgem, 2010a).

The energy supply industry is responsible for funding this investment through borrowing, direct shareholder investment, and retained earnings. However, securing this investment is not guaranteed and will rely on energy companies accessing debt and equity finance. This will require shareholders to be persuaded that a return will come through new assets after the debt is repaid. This in turn requires clear governance, giving a degree of certainty about the future development of the electricity system

4.2.3.4 Technological Failure

The level of reserve capacity and the efficiency of the transport system can have a significant impact on the final costs of the electricity system through the market structure. The physical capabilities of current infrastructure can be measured in terms of their efficiency based on the losses encountered during electricity production and the level of resistance through the transportation system. The effectiveness of these systems will degrade over time, therefore, a time constraint can be put in place by the manufacturer for either replacement or servicing identifying required shutdown periods for certain areas while the maintenance occurs (National Grid, 2011b). This would mean the rest of the network would need to pick up the shortfall and possibly cause constraints on the networks.

Environmental variables such as wind speed –the uncontrollable nature of wind turbines affecting capacity levels - and sunlight levels for solar cell activity can be tracked over previous years to provide an estimated level of capacity and predicted capacity error. However, these environmental issues can cause an unpredictable impact over the long-term, an example of this is the hot summer of 2003 in France causing the failure of many of their nuclear power plants from lack of water (Fouché, 2003).

The ability to provide accurate forecasting of future energy demand trends would require a system which would be flexible over the short and longer term. The possibility of planning issues causing hold ups and blocking vital projects coupled with a failure of policy at a national level leading to a lack of energy infrastructure, and research and development of energy source is a major risk to the structure of the future energy system (Barrett et al., 2010).

4.2.3.5 Resource Availability

The risk generated by primary energy sources is probably one of the most discussed issues in Government and academia (Grubb et al., 2006; Checchi et al., 2009; Kruyt et al., 2009; Barrett et al. 2010; Bergmann 2010; Chester, 2010; Behrens et al., 2011; DECC, 2012g; DECC, 2012o;) With fossil fuels it is the reliance on a stable source of fuel for power stations, heating and transport. With renewable technology there is an issue of rare earth metal resources in order to build the technology and also the environmental concern of the unpredictable nature of its primary resource (Moss et al., 2011; Baldi et al., 2014).

The fossil fuels used in electricity are a finite resource and will at some point be completely exhausted. As fossil fuel reserves decline, limited availability may cause the international price of oil and gas to increase thus driving other cheaper forms of generation to the fore. Over the last decade the price of gas has been strongly linked to the price of electricity and in turn the economy. This therefore has a direct impact on the level of security for the future of the electricity system.

The vulnerability of fossil fuel markets and the resilience of the economy to cope with volatile fossil fuel prices have not been measured in a quantitative way (Jansen & Seebregts, 2010). The unpredictability of the oil and gas markets may be from the inability to predict future relations between states and the possible fluctuations in price due to natural disaster (Barrett et al., 2010).

As a particular technology enters the market with increasing levels of demand, the requirement of the raw materials increases along with it. For distributed generation many of these materials are classified as rare earth metals such as Silicon, Gallium, and Silver (used in solar cells) Gold (in high performance mirrors), Neodymium (used for the magnets in wind turbines) (Baldi et al. 2014). The production of many of these rare materials is dominated by one single country, China, which has 97% of the world's rare earth metal production (Froggatt and Lahn, 2010). The resource deficiency limits the supply chain of alternative generation technologies construction.

4.2.4 Impacts of Risk

Each of the risks discussed above may generate a single or multiple impacts on the energy system. The impacts can be identified as the indicators of energy security (Kruyt et al., 2009). They will lead to a broader understanding of the energy security concept used in this thesis. The impacts include (1) the number and level of blackouts or brownouts experienced on the network, (2) the diversity of the energy supply industry, (3) the market stability, and (4) the end price of energy.

4.2.4.1 Number of blackouts or brownouts

The efficiency of electricity outputs could be considered one of the main indicators for a secure energy system (IEA, 2005). They show immediate signals that the system is not operating correctly. Whether this is the short-term balancing of supply and demand or an external impact of extreme weather events (Lefèvre, 2010). A secure electricity system requires the reduction of involuntary supply interruptions for consumers (BERR, 2007). This is often referred to as 'keeping the lights on' (Patterson, 2009). It is now understood that the security problem is not simply capacity and delivery concerns, it is a multifaceted issue balancing issues of demand and of capacity (McKenna et al., 2011; Darby & McKenna, 2012).

The impact of energy unserved does not only impact economically. There are additional indirect impacts, such as the change in demand patterns; if individuals understand that energy is a fragile commodity consumers would no longer have a reliance on energy being 'on tap'. Greater spikes in energy usage would occur at times of availability making it tougher for network operators to control the system and supply demands.

4.2.4.2 Diversity/dependence

Diversity of fuel source has been discussed as an important method of ensuring supply security, by providing additional sources in the case of a failure in the supply chain and would not be overly dependant on a particular resource (Jansen et al., 2005). Government use it as an important method of strengthening energy security (DTI, 2007a; DTI, 2007d; DTI, 2007e, DECC, 2012n). Measuring diversity can therefore be used as an indicator for this aspect of energy security (Kruyt et al., 2009, DECC, 2012o). A low level of diversity could mean a low level of security. In a means to use diversity as an indicator quantitative measures have been established. Diversity is however, a very complex concept with the energy system. It can encompass, fuel type and sources, technology types, and the range of required skills (Grubb et al., 2006).

Sterling (1999) uses an index of diversity including, variety (the number of different categories[20]), balance (the spread of the categories) and disparity (the difference between the categories). Quantifying diversity in this way provides a structure to measuring diversity through the three indexes, however, it is not an exact science. Measuring disparity requires some form of subjectivity meaning the calculation could be different between models (Kruyt et al., 2009). Each category may have additional aspects, such as increased flexibility or a cheap method of providing baseload. The impact of each of these aspects may be different in the future when compared to the current system.

Diversity is a system property rather than a single aspect, which can be provided by a single technology (Watson and Scott, 2009). It can be quantified to some extent with a level of subjectivity, however, it is not always clear how it should be diversified (Parliamentary Office of Science and Technology, 2012).

4.2.4.3 Market Stability

Market stability is the ability for the system to cope with changes in supply and demand without causing significant movement in the price of energy. This can also be described as 'market liquidity' (IEA, 2002a). Various factors can cause price spikes such as a dependence on a single volatile fuel source such as gas or oil (Bolton, 2013). This makes stability of prices in the market a good indicator for judging historical security.

There are ways of ensuring constant market stability, such as establishing a high level of storage, which would provide a cushion when these events occur. However, ensuring market stability may cause the overall price for energy to increase as storage technologies initially would be expensive (DECC, 2012r).

4.2.4.4 End price of energy for consumers and business

The price of electricity over the last decade has risen after a decade of falling prices (DECC, 2013c). The relative affordability of energy is essential to the security of the energy system for both domestic and industrial consumers.

The end price of energy does not indicate an insecure energy system. It can be a result of insecurity but it is an indicator of risk on the system as discussed in section 4.2.3

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20 Categories are specific to the sector being discussed.

4.2.5 Energy Security Matrix

Each of these dimensions of energy security shows the complexity of the concept. The dimensions identified each have interlinked aspects, which can occur over the long, medium or short time periods. Therefore, in order to illustrate the dimensions of energy security, this thesis has set them out into a matrix (Figure 4-2). This matrix includes the five dimensions of energy security (including the landscape issues, drivers, risks/threats, impacts and the system requirements). Figure 4-2 identifies the landscape issues as the overarching externalities which impact on all the dimensions, whilst at the same time having a direct association with the 'drivers'. It is also important to note that each dimension then influences the following set of dimension. The final dimension shown in the matrix is the system requirements to provide a secure system, which may be able to resolve the other dimensions. The requirements, therefore, directly guide the drivers, making the security of the electricity system, cyclical in nature. Consequently, Figure 4-2 is not designed to be the final representation of energy security, the energy system is a fluid entity and the weighting of different aspects may change with new impacts connections and associations arriving over time.

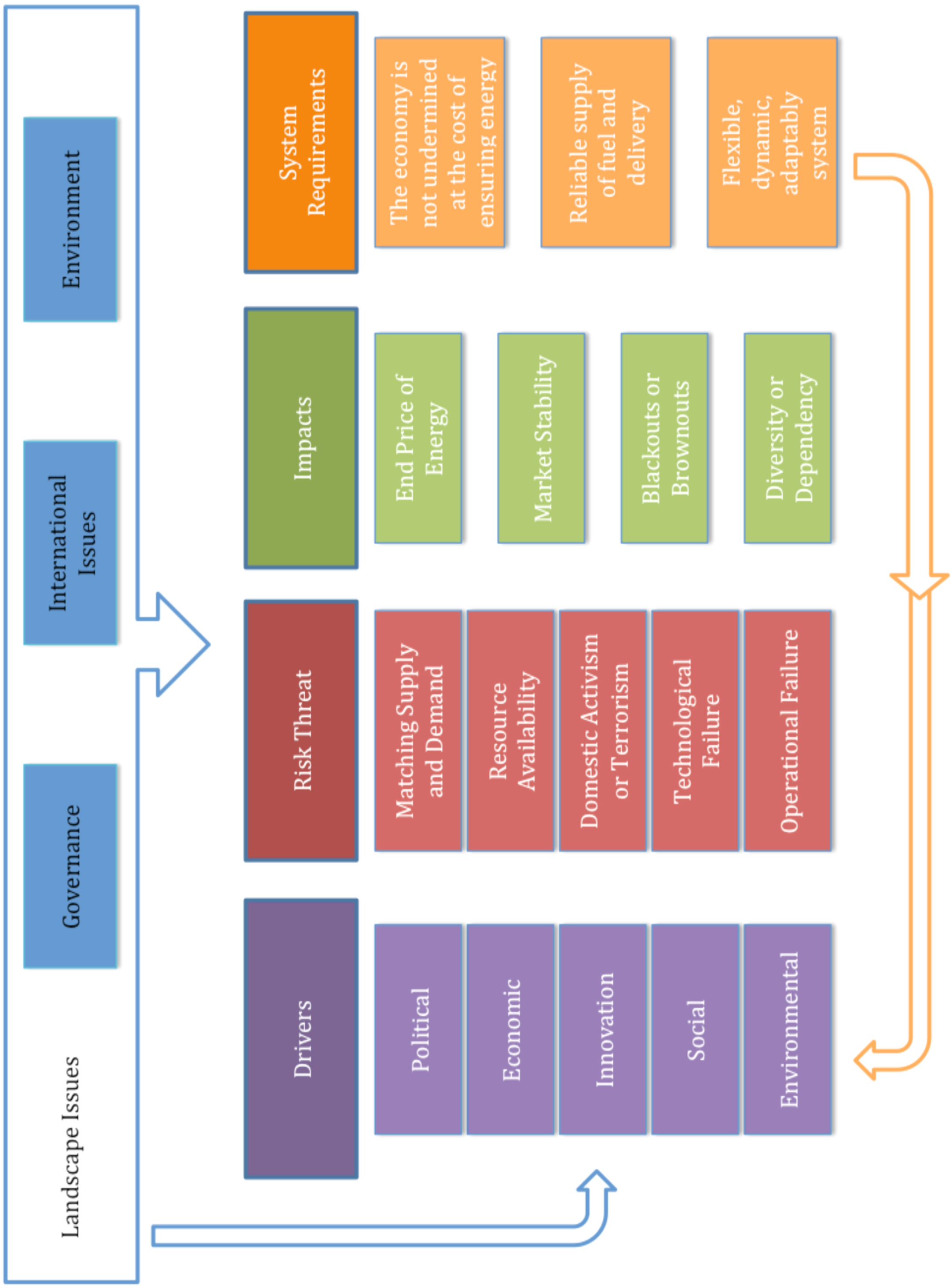

Figure 4-2 Matrix of energy security

4.3 What is a secure energy system?

The complexity of energy security provides a multi-dimensional topic for discussion. When compared to other policy issues, such as the level of carbon emissions or fuel poverty, there is no universally agreed method of measuring or defining energy security (BERR, 2007; Löschel, 2010; Checchi et al., 2009; Kruyt et al., 2009; Chester, 2010). Definitions can be used to describe the reliability of supplies, resilience to infrastructure attack and natural disaster. They can also look at the previous level of interruptions of supplies to end users (HofC, 2011).

This chapter has so far set out the main dimensions of energy security as a way of developing a comprehensive method for defining energy security. This has included the drivers, risks and the impacts of energy security which are impacted upon by the overarching landscape issues.

4.3.1 Key characteristics for a secure energy system

The definition of energy security needs to encompass many different aspects; it is not merely a simple issue of supply. Energy security has many complex facets. The multifaceted nature of UK energy security means that each of these dimensions can be impacted in additional ways, such as the timescale: each dimension of energy security can change over time and can then be separated into the short-term, medium term and long-term elements (DTI, 1997). Categorising risk as a 'shock' or 'stress' is another way in which their relation to time is shown (Stirling, 2009). There is also the interconnected nature of energy security to other systems such as food, water, waste and ecosystem security (Hanlon et al., 2013), where energy security can impact on and be impacted upon by other systems. Finally, the current dependence of the UK energy system on international supply chains and policies could mean there is a link between domestic and international security.

The requirements for a secure electricity system also provide the definition of electricity security. The choice to use these particular requirements has stemmed from the review of the literature discussed previously in this section. They incorporate a classical overview of security of supply with a forward looking approach responding to future changes. In addition to this is the introduction of an economic aspect looking at the cost of security for the consumers and the impact on the UK economy. For the purpose of this thesis the definition of energy security has four aspects discussed below but which have not been placed in order of priority. The significance of each condition will change between different groups and over time:

- The provision of reliable energy supplies for primary fuels and for delivery.
- The energy system needs to be flexible and dynamic in order to respond to unforeseen future changes.
- Protection for the fuel vulnerable in the case of energy price rises.
- That the economy is not undermined at the cost of maintaining energy security.

These requirements are developed from the current discussion on energy security and adapted to fit a holistic model for the modern energy system.

The first aspect, 'the provision of reliable energy supplies for primary fuels and for delivery', is a security of supply statement echoing the older Governmental definitions where the issue was simply to ensure 'the lights stay on'. It is meant to cover the generation and supply of electricity and therefore includes balancing the network (whether this is a supply or a demand based operation) and ensuring the appropriate capacity.

The second aspect, 'the energy system needs to be flexible and dynamic in order to respond to unforeseen future changes', delivers a forward looking concept where the emphasis is on a secure future. A flexible system would mean that you would be able to adapt to changes in demand patterns, technology and externalities such as climate change. This aspect introduces a facet of sustainability into the definition (Barrett et al. 2010). Whereby the electricity system is a continually changing entity and is likely to have different external influences placed on it in 2050.

The third aspect, protection for the fuel vulnerable in the case of energy price rises, is a cost based dimension, which indicates that a secure energy system may not come at the cost of the fuel poor. Ensuring very high levels of security may impact on the end price of energy negatively, and example of this would be having a high level of spare capacity, which would go unused the majority of the time.

The final aspect, that the economy is not undermined at the cost of maintaining energy security, also covers the cost of the ensuring energy security for energy intensive industry players, and the energy industry itself. There is a need for assurance that any policies or mechanisms designed to ensure security do not disrupt other industries impacting negatively on the economy.

4.4 Summary:

This chapter has looked at the development of energy security in Government literature. This has provided an understanding of the concepts held regarding current energy security.

The UK Government uses the term 'security of supply' which could be argued to provide only a narrow definition for discussion, and emphasising secure fuel supplies. This is clearly an important element, but this thesis adopts a far more complex model, including the links to the economy, fuel poverty, the environment as well as ensuring 'the lights stay on'.

This chapter has then identified the dimensions of energy security, categorising them into the drivers, issues, risks, and the impacts and finally provided the system requirements for a secure energy system. The drivers include the social, economic, innovation and political dimensions. These can be discussed in a boarder sense as general drivers for the electricity system. However, for the purpose of this thesis they have been discussed with respect to their affect on security. In addition to the drivers are the issues; the issues can arise from the drivers and dictate aspects, which may need to be resolved or recognised. An example of this is the environmental issues, which include the impact of climate change and play a major role in the shaping of the electricity system futures. Other issues include the planning environment, international associations and the governance of the system as a whole. These issues then follow on to identifying the risks to the electricity system. The importance of identifying and understanding the various risks associated with the electricity system ensure that they are thought about when any policy decisions are made. If any policy for energy security is made it can be seen as only as strong as its weakest link and this is where the risks can break the links. Each risk identified can produce a number of impacts. The impacts can be considered the indicators of historical insecurity. They include the blackout or brownouts, the diversity, the market stability and the end price of electricity.

Finally this chapter has identified a definition of energy security. It has done this by looking at what is required of the system in order to meet all the dimensions mentioned. This thesis proposes that this can be done through meeting four requirements:

- The provision of reliable energy supplies for primary fuels and for delivery.
- The energy system needs to be flexible and dynamic in order to respond to unforeseen future changes.
- Protection for the fuel vulnerable in the case of energy price rises.
- That the economy is not undermined at the cost of maintaining energy security.

With a definition of energy security this thesis will look at the impact of a decentralised electricity system on this energy security. It will do this by firstly identifying what it means by decentralisation. Classifying the aspects of a decentralised system. Then providing the potential benefits and disadvantages of decentralisation for energy security.

5 Decentralised Electricity System's Impact on Security

One of the main changes from a centralised to a decentralised electricity system is the inclusion of a larger number of stakeholders in the energy system. This can be from an increase in the number of operation and maintenance engineers, installers and the owners each of whom would have a 'stake' in the running of the electricity system (Chmutina and Goodier 2014).

A centralised electricity system, could be defined as utilising a few large generation plants, connected to the transmission network requiring the use of the distribution network to connect to consumer; and a comparatively low number of stakeholders who operate within the electricity system.

The definition of decentralisation of the electricity system for the purpose of this thesis includes two main aspects, the technical and the institutional requirements:

- The generation plant would be either connected to the distribution network or off grid, at a location close to the point of use.
- A decentralised electricity system has a greater number of stakeholders with ownership of infrastructure of different scales and dispersed geography.

For the purpose of this study, the level of decentralisation is envisaged as being on a spectrum. It would be unlikely for any system to be considered completely centralised or decentralised. By operating through a small number of main utilities, a single centrally operated transmission and distribution network [21], the current electricity system could be considered highly centralised, with the exception of the introduction of some small-scale technologies through mechanisms such as the FIT.

At the other end of the scale a completely decentralised electricity system would find each consumer having their own personal power source with no requirement for a centrally operated network. The discussion here is to understand the impact of increasing levels of decentralised electricity on the security of the electricity system.

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21 Although there are many Distribution Network Operators, they can each be considered a monopoly for their specific location.

5.1 Aspects of Decentralisation

A decentralised electricity system has, for the purpose of this thesis, been split into five aspects:

1. Policies, including the involvement of UK Government in the development of decentralisation.
2. The economic aspect discusses the approach of markets and market mechanism changes as well as the increase in the number of smaller stakeholders entering into investment.
3. The social aspect includes the impact on and from consumers, individual householders and businesses.
4. The connection of decentralisation to climate change policy.
5. And finally this thesis examines the implications in security of greater levels of decentralisation. This latter aspect is the main focus of this thesis.

5.1.1 Policies

The UK Government's policies and strategies for the future of the electricity system have been outlined in each of the Energy White Papers released over the last 10 years (DTI, 2003; 2007a; DECC 2011b). With changing Governments, ministers and social landscape, the future vision of the electricity system has altered. Concern over climate change has increasingly been the driving force for Government to reduce carbon emissions by 80% by 2050 and which has become a requirement by law under the Climate Change Act (2008). Electricity generation is the single biggest source of carbon emissions estimated at around 32% of the UK's total carbon emissions in 2011 (DECC, 2012a). In addition to this the 2009 Renewable Energy Directive sets out a target requiring 15% of energy to be sourced from renewable technology by 2020 (DECC 2011g). One method of providing a low carbon electricity system is through the introduction of large amounts of renewable generation which can be either large or decentralised (Gullì, 2006; Tsikalakis & Hatziargyriou, 2007; Bergman et al., 2008; Vogel, 2009).

The use of the term 'decentralisation' in Government documents, however, is ambiguous. Therefore, the aspects of decentralisation have to be interpreted within Government documents. The UK Government does not provide a definition for the decentralisation of energy as they have no clear agenda for a decentralised future other than a loose set of concepts. This thesis has provided a clear definition of decentralisation as a means to discuss the issues and impacts associated with a decentralised future.

One reason behind the design of the RO was that it should emphasise the UK's commitment to having a competitive market place. This emphasis on competition between technologies was designed to provide, in theory, the lowest cost generation, keeping the end price of electricity lower for the consumer (Mitchell et al., 2006). Finney et al (2012) discuss the RO as a way to minimise the economic barriers, such as the reduction in investment risk thereby increasing the investment opportunities. However, this was aimed at the larger generators and does not provide a great deal of confidence for the small-scale energy producers (Allen et al., 2008; Williams, 2010; Woodman & Mitchell, 2011). Hence the creation of the FIT.

Another policy support for new micro generation projects was operated through the Low Carbon Buildings Programme (DTI, 2006a). A low Carbon Building Programme provided grants towards the costs of installing micro generation in domestic building and larger distributed generation projects for public buildings.

Other policy instruments to reduce the capital costs of micro generation include the Carbon Emissions Reductions Target (CERT) and the VAT relief for the purchase of energy saving items. CERT is designed to get energy suppliers to provide carbon dioxide emission reductions from the domestic sector. It is a regulated mechanism, which allows 12% of the suppliers targets to be met through micro generation (The Electricity and Gas (Carbon Emissions Reduction) Order, 2008).

There are also less direct mechanisms introduced by Government through Building Regulations. By tightening Building Regulations for new buildings, a move towards zero carbon homes is generated. This was designed to get developers thinking in terms of how to achieve these levels of building standards much more than in the past (Boardman, 2007). In some circumstances this led to micro generation being installed to displace consumption (Bergman et al., 2008).

As the level of decentralised generation increases relative to centralised capacity, it will require different operational systems for control in order to keep a stable system (Cossent et al., 2009; Sims et al., 2011). One solution to aid this is the implementation of greater demand elasticity or flexibility (Romer et al., 2012). One way to achieve this is through smart meter implementation and storage technologies, both of which are discussed by Government but in the early stages of development (DECC, 2012j; DECC, 2012b; DECC, 2013j; DECC, 2013k).

Investment in technology occurs as a result of a risk reward ratio. This ratio differs for different customers. An essential first step, however, is getting the economics right and that is the goal of many Government policies (DTI, 2003; DTI, 2007a; DECC, 2011a). The funding of these mechanisms such as the smart meters and the FIT is achieved through the energy companies who pass the cost on to the consumer through the energy bills.

The Committee on Climate Change has suggested that the policies to meet low carbon objectives will add approximately £110 to each bill by 2020 (CCC, 2011). The use of the consumers' energy bills initially appears to be the easiest and most effective option. The more energy a user consumes, the higher the proportion of the policy they fund. As the growing energy costs from the current reliance on increasingly expensive fossil fuels plus additional environmental and social costs (Ofgem, 2013a; DECC, 2013l) means that the transition to a lower carbon system may come at a high cost, especially to the fuel poor.

5.1.2 Economic aspects of Decentralisation

For any new technology to establish itself within the energy system, it will need to compete with the current technologies. This can be addressed through direct entrance in the market place or through mechanisms and subsidies such as the RO and the FIT.

This suggests that a large amount of investment is to be required for a future low carbon system. Therefore, the future low carbon system will need to be able to support such a large level of investment and introduce investors who can provide this additional investment. It will also mean that the cost of the future system will need to be as low as possible whilst meeting the Government's targets and goals.

The cost of moving to a decentralised electricity system involves four closely linked aspects: the capital cost of the technology, the running costs involved, the profitability of the technology and its ability to find investment. This section will discuss each of these aspects with regards to the impact a decentralised system may have on the current centralised operation.

5.1.2.1 Capital Costs of Generation Plants

The upfront capital cost of distributed generation has been discussed as one of the main barriers to moving to a decentralised system (IEA, 2002a; Pepermans et al., 2005; Allen et al. 2008; U.S. Department of Energy, 2007; Bayod-Rujula, 2009). The Government's Renewable Energy Strategy published in 2008 showed that the smaller micro generation technologies were seven to ten times more expensive than larger scale renewable projects (HM Government, 2009). This is an indication of the economies of scale operating in the renewable sector. However since these publications, the feed in tariff has been introduced and a rapid increase in small-scale technologies has occurred. Furthermore the capital costs have reduced closing the gap between the large to small-scale costs (DECC, 2013f).

One of the explanations for the higher cost of smaller distributed generation plants is the labour cost. The smaller plants are inherently more labour-intensive than the centralised facilities. The result of this, however, is that more jobs are created benefiting the local area (Krager and Hennings, 2009). This provides a dimension of the decentralised electricity generation, which is difficult to quantify. The decentralised electricity technology pathways may cost more in terms of capital costs; however, it has the ability to provide greater economic wealth through an increase in localised jobs and the inclusion of the householder in the investment and ownership of generation plants (Chmutina and Goodier 2014).

Another reason given for the inflated costs of small-scale technology was that before the FIT, the level of deployment was so low that the market was not competitive, meaning the manufacturers and installers were able to keep the costs high (Watson et al., 2008; Bergman and Jardine, 2009). Since the FIT instillations the cost of small-scale technologies has been reducing (DECC, 2012q; UKERC, 2013).

5.1.2.2 Running Costs

In the current centralised system, the market price for electricity currently depends heavily on the price of fossil fuels, which dominate the system. The cost of a generating plant can be grouped as, initial, continuing, fixed and variable costs as shown in Table 5-1 (Gerwen, 2006). These can be either fixed or variable as time and circumstance change (Willis & Scott, 2000). Table 5-1 shows investment cost variables in decentralised generation.

Table 5-1 Characterisation of costs for DG and RES for the UK - timing of expense (Gerwen, 2006)

Type of Expense	Initial	Continuing
Fixed	Engineering cost Investments Licensing cost	MW-based distribution tariffs Fixed taxes Scheduled maintenance Insurance
Variable	MWh-based connection cost	Unscheduled maintenance Fuel cost Fuel taxes MWh-based distribution tariffs

For many of the small-scale renewable technologies such as solar, wind and tidal the cost of the input fuel is zero. This reduces the running costs of these technologies and also makes future cost predictions easier to make. However, because of the dominance of fossil fuel generation such as the Combined Cycle Gas Turbine (CCGT) the market price of electricity is driven by the price of gas (UKERC, 2012).

The fuel costs associated with CCGT can be highly volatile and relative with unpredictable changes to future markets. The issue with this is that it means that although the running costs of renewable generation does not have the variable fuels aspect, they are impacted upon with the wholesale cost of the electricity (Roques et al., 2006).

5.1.2.3 Profitability of Generation

The profitability of decentralised electricity technologies are linked to the running costs and the upfront capital costs which have to be outweighed by the amount of money it earns to make it profitable. The main feature in a technology's profitability is the electricity market arrangements, mechanisms and subsidies. In the 1980s the liberalisation of the electricity and gas markets opened up the ability for competition to control the market and since then there have been numerous adaptations to the system. However, there is wide spread recognition that the current operation favours the centralised technologies in both the market rules and the approach within which it is regulated (Wolfe, 2008; Woodman & Baker 2008; Watson & Wright, 2010).

In addition to this the current electricity system could be said to be locked into a centralised ethos of operation (Rutledge, 2012; DECC, 2013a). Many Government policy statements talk in terms of 'levelling the playing field' for decentralised investments (DTI, 2006a). Other bodies have called for more fundamental reform of regulatory systems, for example, a change to the energy regulator's duties so that they place more emphasis on Government environmental and social targets (Helm, 2007; SDC, 2007). This emphasis on change is dominated by the centralised operation through mechanisms and subsidies, which guide the larger utilities to enact change (Mitchell, 2014a).

Establishing the profitability of a project is a fundamental link to ability to find investment which is discussed next.

5.1.2.4 Investment

Increased decentralisation of the electricity system is bringing major changes to the investment scene (Bloomberg, 2011; REN 21, 2014). Decreasing the capital costs of each unit is providing the incentive for these stakeholders who normally would not invest in the energy system, to buy into assets (Chmutina and Goodier 2014).

The promotion of renewable generation may have a negative impact on the investment to the conventional generation that provides the short-term back-up required today. As the level of variable renewable generation increases, the requirement for flexible back-up technologies will also increase. Therefore, there needs to be an additional mechanism which will ensure retaining or replacing the back-up generation to be financially viable whilst developing a decentralised electricity system.

A recent study by Poyry (2010) identifies a concern for the volatility of the electricity market as the level of low carbon generation increases. The volatility of the market may also change from year to year with weather variations, making it difficult to predict the supply abilities and so undermining the case for investment in new plants.

5.1.3 Social

Historically the consumer could be considered to be removed from the operation of the system and any direct involvement in its primary decision making. Consumers are given very little choice in how the energy system operates other than from whom they buy their electricity (Parag & Darby, 2009). Up until recently, most consumers appear uninterested in their energy provision, beyond being able to switch on a light (Ofgem, 2013g). To the degree that customers that do care would likely be looking for energy services that are best suited to them. This means that not all customers will be looking for the same feature of the electricity system and therefore weighting different aspects accordingly.

There has been increasing discontent by the public over rising prices and reflected in the Labour Party leaders recent speech (Miliband, 2013). Britain is at a new stage of energy policy in the run up to the 2015 election. Motivating the end user to connect actively with their energy use may lead to reduced energy use and therefore reduced energy bills. This aids other policy goals such as carbon reduction and if managed effectively could improve fuel poverty as well as energy security. (UKERC, 2009)

Decentralised electricity generation offers the opportunity to engage householders, businesses and communities further. It does this by encouraging greater awareness of their energy behaviour. An individual consumer has very little impact on the energy system, however, their actions can have a causal effect on other consumers and when looked at as a single actor group consumer, their influence can be great. Therefore, the behaviour of this actor group in terms of their day-to-day consumption patterns and their willingness to become involved in the energy system is important and needs to be taken into consideration. The importance of user behaviour is vital to the uptake and use of decentralised generation. But there is an argument to suggest decentralisation is not being used to its full potential at the moment (Keirstead, 2008; Manfren et al., 2011)

Much of UK policy centred on small-scale electricity generation is focused on deployment and often ignores behaviour after implementation (Bergman et al., 2008). One example of this is the Feed in Tariffs. The FIT provides an incentive for generating electricity and an incentive for reducing consumption known as the export tariff. However, the export tariff, rate of return on what is exported back to the grid, is set at 4.5p/kWh (Ofgem, 2012), which, in comparison to the level of return from simply generating, leaves very little incentive for reducing energy consumption (DECC, 2012i). By increasing the export tariff, consumers would have a greater incentive to reduce consumption.

A major shift in user behaviour patterns could lead to production and consumption models also changing. Whether the behaviour patterns of consumers are changed through the uptake of decentralised energy or vice versa, ultimately, a successful paradigm shift could provide a higher uptake of decentralised generation, increased understanding and awareness of energy production and consumption, and emissions reductions (Bergman et al., 2008). This increase in engagement with the electricity system has the possibility to lead on to consumers becoming energy citizens or energy co-providers, thus playing a more active role in the energy system (Sauter and Watson, 2007; Chappells et al., 2000).

Consumer engagement can be achieved through a variety of methods such as increased information schemes providing a better understanding of the operation of the energy system, or through the consumer having a greater level of ownership of production and transportation technologies (Dobbyn and Thomas, 2005). The level of engagement can change in relation to the type of energy system (centralised or decentralised). Table 5-2 has been adapted from Forsight final project report Powering our Lives: Sustainable Energy Management and the Built Environment (GOfS, 2009). It shows four routes for public engagement at the extreme of the spectrum looking at centralised, decentralised, engagement and disengagement.

Table 5-2 Routes for public engagement and scales of energy systems (GOfS, 2009)

Level of engagement	
1. Centralised disengagement	2. Centralised engagement
3. Decentralised disengagement	4. Decentralised engagement

Centralised disengagement is a business-as-usual scenario where the consumers are largely disengaged from their energy usage beyond bill payment. The only engagement they have is the ability to change energy supplier or the manner in which the energy bill is calculated.

Centralised engagement would require a great deal of information rolled out to consumers included with the deployment of smart metering technologies. This enables consumers to track their usage levels and adapt to time of use tariffs which the smart meters could facilitate.

For **decentralised disengagement** the small-scale electricity generation is generally owned and controlled through large companies with automated systems so the householder has minimal interaction or involvement. Essentially, the billing and metering system provide the only interaction, however, the nature of decentralised generation is that it is geographically dispersed which means there will be an increased engagement over a centralised system.

In the **decentralised engagement** scenario the ubiquitous nature of energy becomes more visible. Consumers are able to see electricity generation every day in their locality even at home. Most distributed energy technologies incorporate a facility for monitoring their output and level of consumption. This helps to generate increased awareness for the consumer, leading to improved conservation (Wolfe, 2008; Chmutina and Goodier, 2014) also see section 2.11.1. In addition to this, smart meters will provide the opportunity for householders to play a stronger role in managing energy at home (DECC, 2013j).

The UK environmental policies and targets are an important driving force towards change in the electricity system. Government policy has a direct impact on promoting renewable energy through targets (see section 2.5.3). Regulations also play a part by incentivising stakeholders to look for cleaner and more cost efficient solutions to energy production and consumption (Pepermans et al., 2005).

5.1.4 Environmental Aspect of Decentralisation

Government needs to find a path to a low carbon future. This could be using the current centralised operation to meet the targets set by Government, or a change to a predominantly decentralised system or somewhere between the two. The implications of scale on different scenarios have been explored in depth in the past, including Royal Commission on Environmental Pollution, Tyndall Centre for Climate Change Research and by Ofgem (Watson & Wright, 2010). Both a centralised and decentralised electricity system would be able to meet the Government's goal. The discussion, therefore, should come down to other factors including which is more or less costly to the Government, and ultimately the consumer and which best meets the goals of energy policy and which is most acceptable to society.

The costs of meeting climate change targets will be significant, but are expected to be much lower than the costs of inaction (Stern, 2006). However, it is not easy to predict which pathway would be least costly (Watson & Wright, 2010).

The effect of decentralised electricity generation on the environment takes three forms:

1. Its ability to change consumer behaviour. There have been a number studies which indicate that small-scale generation close to the point of use can have a positive impact on the energy behaviour of consumers (Keirstead, 2007; IPPR, 2009; Cabinet Office et al. 2011).
2. The emissions of CO_2 levels during electricity production. The implementation of renewable generation reduces the requirement for fossil fuel burning power stations, in turn reducing the level of CO_2 production (UKERC, 2006; Krager and Hennings, 2009). However, with the level of intermittency shown by renewable generation, they cannot replace the fossil fuel generation on a like for like basis (UKERC, 2006; Sims et al., 2011). Nevertheless intermittency of renewable generation causes fossil fuel power stations to be run at a lower output, thus reducing their efficiency.
3. The third area of decentralisation's impact, occurs with the conservation of materials. The construction of a large number of smaller plants results in larger consumption levels than with the construction of a small number of larger plants (Krager and Hennings, 2009, Bergman and Jardine, 2009).

5.1.5 Energy Security

Energy security, as discussed in Chapter 3, plays a major role in the policymaking for the UK electricity system. The low carbon objectives set by Government mean that in the future, the operation and technology of the electricity system may need to change. One way to do this is to move to a more decentralised model, with higher levels of small-scale renewables, storage, demand-side management and more consumer engagement but not at the expense of security. This section will discuss the impact of moving to a more decentralised electricity system for energy security.

5.1.5.1 Technical Impacts of Increasing Levels of Variable Power On Security

Decentralised electricity generation has the ability to engage with consumers and to provide access to low carbon renewable generation technologies (NESTA, 2010). However, the depth of literature discussing the relationship of decentralisation to energy security is narrow. The majority of literature focuses on the technical engineering aspects including small-scale generation on the electricity network. This is divided into two sections: firstly, it deals with the technical issues of increasing levels of decentralised variable power. This debate has been on-going for several years and there are those who continue to argue that variable power increases insecurity (Grubb et al., 2006; Strbac et al., 2009; Kubik et al., 2012; Trainer, 2013)

However, as can be seen from other countries such as Germany and Denmark. It is now clear that introducing variable power into an electricity system requires new operation and management which is different from the operation and management of centralised non-variable electricity but not more insecure (Coafee, 2008; Lund and Mathiesen, 2009; EPIA, 2012; Chmutina and Goodier 2014). Secondly, the section identifies the potential non-technical benefits of decentralised electricity for security.

Technologically there are difficulties in using the current distribution network with larger volumes of generation as shown in Box 5.1. Although all of these issues are well understood within the engineering sector, there is an inherent lack of experience in dealing with these issues in Britain although not elsewhere (House of Commons, 2010).

Box 5.1

- Accepting bi-directional power flows – changes in generation levels may mean that distribution networks will need to re-direct power back to the transmission system
- Maintaining electricity flows and voltage variations at a level that is consistent with equipment ratings
- Ensuring power flows from load generation do not create short circuit currents in the event of network faults.

These issues can be discussed as the 'power quality' of the network, encompassing the reliability provided by the system (Coll-Mayor et al., 2012). Power quality refers to the characterising of the voltage and current waveform and how they are aligned, how it can be affected by dips and interruptions from switching operation in the network, together with network disturbances, such as fast voltage variations (Pepermans et al., 2005).

The effect of distributed generation on power quality is complex as it can contribute to regions where voltage is low as it generally provides a rise in network voltage levels (Strbac et al., 2007). However, introducing a large amount of distributed generation causes bi-directional flows, complicating the system dynamics (Pepermans et al., 2005). The bi-directional flows of electricity mean that the distribution network becomes overloaded and needs to send power to the transmission system which, currently, cannot accept the generation for engineering reasons. There are also difficulties found at an operational level from a balancing and regulatory perspective (Gerber et al., 2012).

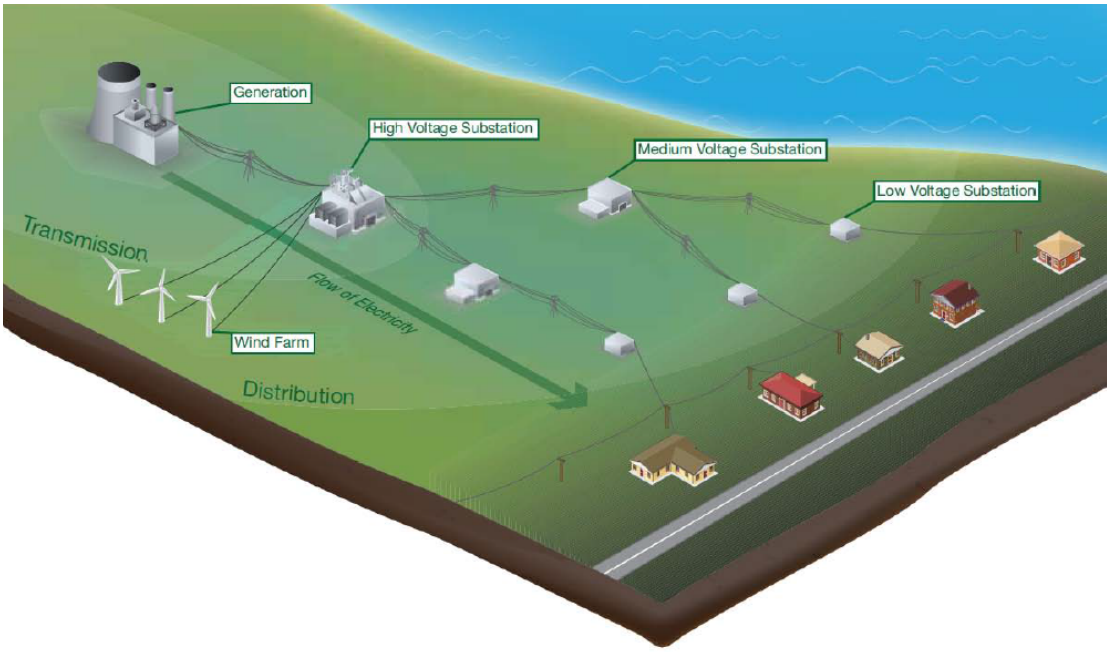

Figure 5-1 UK Centralised electricity network operation (DECC, 2012r)

In order to compensate for an increase in distributed generation, the distributed network operator's future is likely to be very different. Currently, the distribution networks operate passively, with little or no requirement for operational management (Jenkins et al., 2000; Sims et al., 2011). The System Operator[22] balances the flow of electricity but it is possible that in the future the DNO's will become system operators as well. This will require a management of greater flow of power, often including the export of electricity back to the transmission system (Wolfe, 2008; House of Commons, 2010). Changing the operation of these networks from a passive circuit simply supplying load, to an active management based system where power flows and voltages requires changes in both supply of generation as well as the time and amount of demand (Jenkins et al., 2000). To achieve this, a certain level of upgrade, reinforcement, or replacement of networks may be required (Woodman and Baker, 2008; Ofgem, 2010a).

Distribution network operators are paid by the utilities for use of the network. The cost of which is then passed on to the consumers (House of Commons, 2010). The management of a distribution system is likely to require new models of control and co-ordination, in comparison to the centrally planned system which provides

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22 In the UK the System Operator role is run by The National Grid Company who also own the Transmission Network.

electricity one way from generation to consumer (Foresight, 2008). By entering into a more active role, the complexity from the new control and co-ordination models increase the end cost to the consumer, but equally if consumers become more involved it may reduce their bills through energy efficiency (Davenport, 2013; ECCC, 2013).

An active role for the DNOs is both new internally to the DNO but also in respect to the relationship between the DNO and transmission operator. This may be received as an additional risk. Therefore, without the right regulatory incentives the distribution network operators may try to keep their current passive operation, obstructing the development of the networks (Mitchell, 2014b).

The additional complexity from active DNOs could also be carried on to the System Operator. If the number of generators supplying electricity to the grid increases, the System Operator will only have direct communication with the larger licensed generators. Without sufficient communication between generating stations, any increase in decentralised electricity generation would be likely to elevate capacity uncertainty. Therefore, as well as having to predict the level of demand with some uncertainty, the confidence in estimated supply levels may be reduced, making the 'predict and provide' nature of the electricity system more complex (DTI, 2007; House of Commons, 2010).

This evidence is disputed, and the potential impacts of variable power are often exaggerated (UKERC, 2006; Watson and Scott, 2009; Mitchell 2014b). The UKERC (2006) report has shown us that there is also a strong argument behind intermittent generation of a distributed network not compromising the current electricity system until it reaches 20% of electricity demand. After this, changes to the electricity network would be required (ECCC, 2013).

Changes could include developing demand response technologies and backup generation as and when required in order to help in the balancing of the network.

Balancing the electricity system is a two way process which could also be provided by changing the demand profile with demand response technologies and storage solutions. Each of these solutions require investment into electricity infrastructure, therefore, the economic impacts of moving to a decentralised electricity system are increasingly more important.

5.1.5.2 Non-Technical Benefits of Decentralisation to Security

5.1.5.2.1 Brining the DNOs to 21st Century Technologies

The current strategy for the 14 Distribution Network Operators (DNOs) within the UK is to operate the networks on a passive basis, transporting power from the transmission network to the consumer (as discussed in section 2.7.2). With more generation connected to the distributed network, the DNO's will have to play a greater role in the system operation. This increase in activity will require the replacement or reinforcement of much of the distribution network (National Grid, 2011b).

In 2005 the Energy Networks Association showed that 70% of the current Network is reaching the end of their designed lifetime. This means that instead of simply replacing like for like there is the opportunity to enable more active management for the DNO's (ENA, 2005). However, this opportunity has not been well used; the regulatory structure for DNOs does not provide enough incentive to work on longer-term development plans. The 'Use of System Charges' from distributed energy connected to the network incentivises the DNO to increase the efficiency of their network rather than develop new innovations. In addition to this the biggest proportion of their revenue comes from charging consumers, meaning the connection of new generation to their network is a low priority (Awerbuch, 2004).

There have been additional mechanisms to promote DNO network innovation, including the Innovation Funding Incentive, Distributed Generation Incentive and the Registered Power Zones each of which commenced in 2005 (Ofgem, 2005; SP Power Systems, 2005).

However, these had limited success in the past with very little up-take (Ofgem, 2008; Woodman & Baker 2008). More recently the Low Carbon Networks Fund (LCNF) has been established, specifically targeting funding that allows up to £500m over five years to support new projects and try out new technologies (Grünewald et al., 2012). The objective is to provide DNOs with a better understanding of what is required to enable a low cost low carbon secure system (Ofgem, 2010c). Instruments that operate from outside the regulatory process such as the LCNF work well to promote research and development projects, however, the regulatory process of funding the networks may need to be redesigned in order for these projects to run over a sustained period (Lehmann et al., 2012). For the UK this has begun with a new regulatory approach (RIIO) (see section 2.3.1) which puts security and sustainability at the top of the agenda and recognises the need for system transformation (Ofgem, 2010d). However, the performance of such objectives is still yet to be seen.

5.1.5.2.2 Flexibility

Providing a *dynamic* electricity system is a major aspect to ensuring energy security, as identified in section 4.3. A dynamic electricity system is one that can react to any circumstance, short and long-term. For example, in the short-term this means the balancing of supply and demand. The current balancing of the electricity networks is mostly achieved through the supply industry where the generation is dispatched to meet demand levels (National Grid, 2011b). However, the inclusion of any demand side involvement has the ability to not only improve the security of the electricity system but also to reduce the required investment into additional capacity (DECC, 2011a). For the longer term this is the ability to adapt to changes in consumption such as future demand levels, patterns and requirements. These can be from an increase in demand for electrification of heat and transport, changes in peak demand times (or less-predictable peak demand) and a requirement on the electricity system to reduce overall carbon emissions.

In order for supply to meet the future changes to demand, the supply side would need to be flexible. Distributed generation technologies may provide the ability to adapt to the changing economic environment as and when required. The associated size and scale in comparison to the centralised plants means they have shorter construction times and can develop at a faster rate (Pepermans et al., 2005; Purchala, 2006).

It is important to note, however, that public resistance to the development of wind energy and landfill gasses can cause substantial lead times and delays (Devine-Wright, 2005). Planning is still an issue for the implementation of distributed generation as it is for the centralised operation. For example, in the 1990s it took over 6 years to acquire planning consent for a 50 mile stretch of new high voltage power lines in North Yorkshire. More recently upgrades to the 137 mile line between Beauly near Inverness and Denny near Falkirk will have taken 13 years when it is due to finish in 2014 (Howard, 2011; BBC, 2011).

5.1.5.2.3 Diversity

Another aspect of delivering a flexible secure electricity system is to increase diversity. The diversity of the electricity system encompasses the fuel type and sources, technology types, the location of generation and the range of required skills (Grubb et al., 2006) as discussed in section 4.2.4.2.

The 2007 Government White Paper shows how using a much wider range of producers reduces the impact from any one generator (DTI, 2007b). Decentralised electricity generation provides a system with a wider range of producers, which includes additional resilience to temporary outages and failure, in comparison to the current centralised model (IEA 2002b; BERR, 2008). This can be illustrated by the failure of a single small plant having a much lower impact than the failure of a large facility simply because of its size and its proportion of electricity capacity. This is, however, only if the smaller plant is still centrally operated and is not the sole provider for a specific area (Krager and Hennings, 2009).

Establishing greater levels of diversity is not a single answer to delivering energy security. Any additional technology introduced to diversify the system would need to be able to operate alongside the current technologies and be able to meet the other aspects of security. Without this the increase in diversity would be removing secure sources of generation thus reducing the overall security.

5.1.5.2.4 Removing Dependency on Insecure Supplies

The future of the electricity system is likely to be dictated by the requirement for the reduction in carbon emissions. In addition to this the current natural resources required means that even without carbon targets set by the Government, the way in which electricity is generated and consumed would need to change.

Economic assessments of the impacts of an insecure electricity system are typically uncertain and for the purposes of policy making inadequate for assessing the risk to security (Lefèvre, 2010). Fossil fuel resource concentration is one way of quantifying a specific aspect of security, distinguishing between the price and availability of a primary resource. Most electricity generation technologies are supported by some financial subsidy in some way, such as the Renewables Obligation, each of which has an impact on consumers' energy bills, however, this impact is low. There is clear evidence to suggest that the main driver for the increase in consumer bills is the wholesale price of gas (CCC, 2011; EDF 2012;

Krager and Hennings, 2009). This means the current system places a lot of emphasis on the supply of natural gas as a primary resource for the future (Rutledge, 2007; Barrett et al., 2010).

The current electricity markets are dominated by the price of gas and the cost of its generation, so if a large amount of alternative generation were to flood the market, then the CCGT plant profitability may come into question. Any unreliability in the future price of gas will require strong policy mechanisms to support it in order for the investment to be found. The Electricity Market Reform package contains the capacity payments which have been designed to provide financial incentives for generation at peak times (DECC, 2013h)

The increase in the level of non-fossil fuelled generation would reduce the UK's dependence on gas in the longer term. This means it would also help stabilise the end price of electricity, as it is no longer dependant on a single resource (Ofgem, 2011b; Parliament, 2012). A large proportion of the decentralised electricity generation is made up of renewable technologies where the primary resource is, by its nature, not going to run out. As a result increasing their share in the energy mix can help to reduce the dependence on imported fossil fuels.

> *"An increased use of DG may reduce the demand for imported gas to some extent. Although gas-fired CHP uses gas more efficiently than centralised fossil-fuel electricity generation, it is not clear whether a wider deployment of CHP would lead to an overall decrease in gas demand" (DTI, 2007b).*

From a security point of view removing the UK's dependency from unstable geopolitical regions will only help in security. The European Commission's study (2006) on future *Scenarios on Energy Efficiency and Renewables* report has shown that doubling the share of renewables in electricity generation by 2030 would reduce import dependency by about 6-7%. Similar conclusions were reached by an assessment of EU energy policy analysis published by the Energy Research Centre of the Netherlands (Groenenberg et al., 2008). Having said this the importing of fuels into the UK may not always be considered a risk to security. By importing the resources, an additional level of diversity is added to the UK's energy system. It could also be argued that the exporting nations may have a certain dependency on selling the resource, as does the country buying. The idea of becoming completely self-sufficient means that any domestic issues will be exacerbated by not having the international supply chains in place already. An example of this is in the 1990s when the UK sourced all of its natural gas supplies from the North Sea. More recently with the North Sea resources reducing, the UK found itself with very little infrastructure for importing gas (Bolton, 2013).

5.1.5.2.5 Demand and Supply

The current relationship between the consumer and the energy system is one of being very removed from how the system operates. Consumers are given very little choice (other than who they buy their electricity from) in how the energy system operates and can be considered passive (as discussed in section 3.2.1). A move is needed from 'consumers' to 'customers' where the costs are justified (Mitchell, 2000) and users are given the option of being able to support the energy system to deliver its goals. Greater decentralisation may motivate and engage the end user and this may increase security through a range of ways (UKERC, 2009). This thesis will explore this further.

Consumer behaviour is becoming a key element in developing energy security concepts with their capacity to transform where the energy comes from, the end-user consumption intensity and when it is used. Examples of this are during the winter of 2005 to 2006 where many customers decreased demand as a reaction to problems in the energy market which were stemmed, in part, from actions taken on the continent and in Russia, together with the state of the global LNG market or in Japan at the Fukashima incident (IEA, 2007; Froggatt et al., 2012). In these instances consumers changed their behaviour in order to maintain security of supply.

An increase in a consumer's connection to the energy system may come with an increase in their reliance on a secure system. For example, an increase in demand from electrification of transport and heat sectors would mean an increase in consumer dependence on electricity. Therefore, consumers may take more of an interest in the cost of electricity and its availability. Darby (2010) posed the question of how an increase in consumer reliance on electricity security would change their willingness to adjust behaviour.

Decentralised electricity generation offers the opportunity to engage householders, businesses and communities, through the 'hosting' of small-scale energy projects in schools, supermarkets, and hospitals identifying the possibilities around alternative energy sources and through more visibility because of increased number of plants (BERR 2008; UKERC, 2009). The 2007 Energy White Paper discusses the benefits of decentralised electricity generation in terms of security of supply through the behavioural impacts of 'closeness' to their power source. This engagement encourages active demand throughout the day, reducing peak loads on the system, and promoting a greater level of efficiency among consumers (DTI, 2007b; IPPR, 2014).

Additionally, most distributed energy technologies incorporate a facility for monitoring their output and level of consumption, helping to visualise their consumption and generate increased awareness (Wolfe, 2008). Furthermore, a greater involvement in the electricity system also extends to the use of technologies which could accompany the small-scale generation such as dynamic demand helping to balance the system (Delta, 2010).

Preferably any policy which encourages decentralised electricity generation would need to be supported by incentives to reduce energy demand (Behrens et al., 2011). Technologies such as 'smart meters' would enable time of day usage for certain services providing the user with the ability to reduce overall costs. However, the cost of moving to a decentralised electricity system has been discussed as overly expensive in comparison to the way in which the UK operates today (see section 5.1.1). Having said this the cost of moving to a low carbon electricity system, whether it is centralised or decentralised, is going to mean a rise in fuel bills for the householder see section 2.4.2

5.1.5.2.6 Economics of Decentralised Electricity Generation

As discussed in section 5.1.1 there are system wide economic benefits of decentralisation. Onsite production of electricity could remove the requirement of transmission and distribution costs which can amount to approximately 19% of the electricity cost (see Figure 5-2, DECC, 2013m). Generating electricity closer to the point of use can reduce losses; about 1% of electricity is lost in transporting it across the transmission system and 6.5% in distribution (Ofgem, 2007a; BERR, 2008; Mitchell, 2014b). This can mean that decentralised electricity generation increases overall system efficiency, by reducing transportation losses, leading to lower generation and network costs.

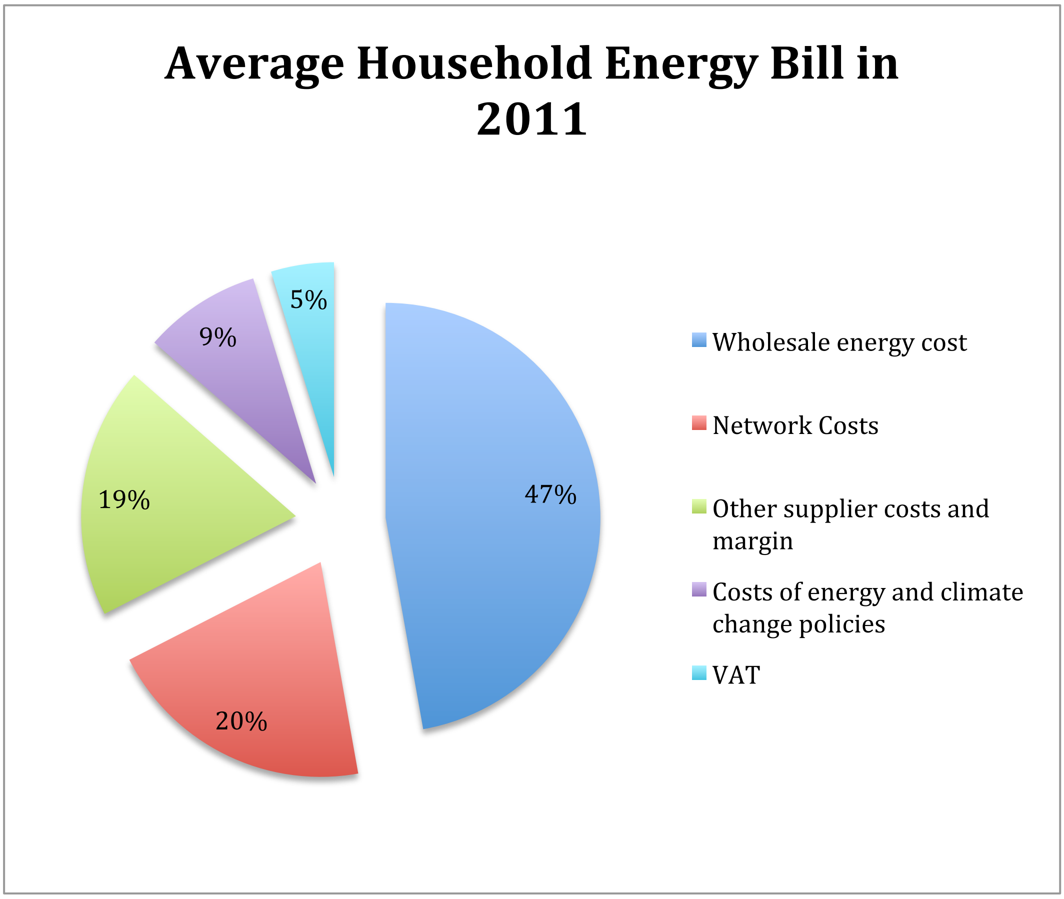

Figure 5-2 Breakdown of average household gas, electricity and energy bill in 2013 (DECC, 2013m)

One of the main barriers to implementing a new regime for the electricity system is whether the investment can be found for the new technologies.

Ofgem have shown a requirement for finding up to £200bn worth of investment up to 2020 in order to meet the Government goals of a low carbon secure system. An on-going discussion is whether this total amount is necessary and if preferable a centralised or a decentralised electricity system.

A decentralised electricity system not only introduces more small-scale electricity into the energy system, it also introduces more smaller actors from householders, communities and businesses which previously would not have invested into this area. The FIT investment has been substantial (see section **Error! Reference source not found.**) and there are now over 379,122 installations as of 31st March 2013. The attraction of local initiatives in part demonstrates that alternative energy service business models (which are not reliant on selling more energy) can be profitable. In addition, this initiative offers the potential to jointly address issues of demand-side management, energy poverty, local siting, electricity and heat production in ways that existing electricity and gas companies have been reluctant to do, and connection to energy use in general. If these local networks were to develop significantly, they might duplicate some of the existing network infrastructure while offering more choice, more network resilience and lower costs (Jamasb, & Pollitt, 2008).

5.2 Summary

This chapter has identified the key impacts of moving to a system of high levels of decentralisation on energy security. It begins by providing a definition of what is meant by decentralisation including two main aspects, the technical and the institutional requirements:

- The generation plant would be either connected to the distribution network or off grid, at a location close to the point of use.
- A decentralised electricity system requires an increase in the number of stakeholders with ownership of infrastructure.

This chapter explores aspects of decentralisation which are deemed important to the electricity system, including: the policies, economic, social, climate change and finally energy security.

The benefits of decentralisation for energy security include the flexibility, diversity, its reduced dependence in insecure supplies, the links to demand and how the decentralised electricity may be a benefit for system economics. The flexibility of an electricity system is important in order to react to changes in the drivers of the electricity system. A decentralised system has the ability to be implemented in a short time scale, with low lead times for builds and can therefore develop at a faster rate than centralised system. Decentralisation also inherently incorporates a high level of diversity in its generation mix from technology type, primary source, supply chains, skills and location, providing an increase in security against any technical threat. The diversity of primary resource also identifies the fossil fuels dependence on an insecure resource which has been controlled by the volatile price of natural gas. Cost of generation could be considered as one of the biggest drivers of the technological direction for electricity in a competitive market place. Therefore the high capital costs of renewable technologies have to be subsidised by Government until market parity is achieved. Government has identified that for solar photovoltaic generation this may be the first renewable technology to be deployed without subsidy. Although they also identify that it would not be until the mid to late 2020s (DECC, 2014e, Elliott, 2014).

However, whether it is a centralised or decentralised low carbon system, investment needs to be found. One advantage of a decentralised system is that a large number of additional stakeholders are introduced into the industry possibly opening up the opportunity to find investors.

This chapter has provided a definition of a decentralised electricity system, identified its main aspects and discussed the negative and potential benefits for energy security. However, the move to a decentralised electricity system requires a large scale technical change. Therefore the next chapter will be used to discuss transitional theory and the different approaches to technical change.

6 Theoretical Approaches to System Change

The current electricity system could be considered highly centralised and dominated by carbon intensive electricity generation, delivered through transmission and distribution networks. Current policy is focused in part on how to move towards a lower carbon system (as discussed in chapter 2). This thesis has discussed two possible options: low carbon centralisation with the use of nuclear and carbon capture and storage, or low carbon decentralised system with the use of small-scale renewable generation, backed up with electricity storage and demand management technologies.

This chapter will begin by discussing the UK's current lock-in to a centralised electricity system. It will then discuss different theoretical approaches, which may be appropriate in understanding a shift towards a decentralised system, focusing, in particular on Geels' Multi Level Perspective approach. The chapter will then go on to discuss how governance can be used to promote a transition and to provide a secure electricity system.

6.1 Lock-in to Centralisation

Roughly 86% of the UK's electricity is generated from large scale coal, gas and nuclear power stations (Rutledge, 2012; DECC, 2013a). This reliance on large scale generation indicates that the electricity system could be considered as 'locked-in' to a centralised model in the sense that certain technological or systemic characteristics are dominant and that other technologies will therefore struggle to establish themselves. In order for a decentralised electricity system to become established it will have to overcome this lock in and establish new system structures (Ahman & Nilsson, 2008; Unruh, 2000; Safarzynska et al., 2010; IEA, 2011; Markard et al., 2012).

Lock-in may not always be due to inherent low cost or performance ability of a technology; its dominance could also be a result of its market share, influencing decision makers and ultimately ensuring the incumbent approach remains (van der Vleuten & Raven; 2006). Within the electricity system lock-in is often linked to issues such as the sunk investments into a specific technology, organisational and market structures as well as user practices and lifestyles (Rip and Kemp, 1998; Smith et al., 2005; Geels, 2010; Markard et al 2012). Other factors such as subsidies, regulation, business models and the vested interests of major stakeholders can also play a role in consolidating technological dominance (Bento, 2010). By increasing the proportion of a particular technology type means that the system may become reliant on this this technology and therefore these factors will be developed towards the locked in, thus developing a coevolutionary perspective on the lock in. This would make it more beneficial for actor groups to work together to develop a single stand of thinking (such as a centralised or decentralised paradigm) (Foxon, 2010).

These issues around the lock-in of a particular system or set of technologies can also be seen as a 'locking-out' of specific technological pathways. So, for example, the design of the electricity market (see chapter 3) and the penalties it imposes for imbalance means that intermittent generation technologies are at a disadvantage entering the market in comparison with established, predictable fossil fuel or nuclear generation (Sambeek, 2000; IEA, 2002b; Joskow, 2006).

6.2 Transition Theory

In order to move from a carbon intensive system to one of low carbon, secure and affordable generation and transportation, a non-linear regime[23] change will have to occur. During the 1990s the concept of a transition found its way into the research of technical innovation and sustainability (Verbong and Loorbach, 2012; Rip and Kemp, 1998; Schot et al. 1998; Rotmans, 2001; Kemp et al., 1998). This section analyses the transition theory and how this move can occur or the possible barriers to transitioning. It will then look at the impact of moving to a low carbon centralised system or a low carbon decentralised electricity system.

Using transition theory in the move to a sustainable energy system is not a new concept. The Dutch Government have conceptualised the move to sustainability through transition management (Kemp and Loorbach, 2006). The policy orientated theory developed in the Dutch academic system has been translated into practical actions in the energy policy field (Kern and Howlett, 2009). In 2001 the Dutch Government changed its policy plan adopting a transitional approach seeking a more sustainable socio-technical system (Smith and Kern, 2009)

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23 A non-linear regime change is a new development pathway which consists of the dominant set of rules and policies, which are supported by the actors and the infrastructure which comes with them (Rotmans and Kemp, 2001; Smith et al., 2005).

6.2.1 Why look at transitions?

The desired policy outcome for the energy system is for it to be low carbon, secure and affordable (DTI, 2003; 2007a; DECC, 2011a). These three outcomes can be seen as 'persistent' (Rotmans et al., 2001; Rotmans & Loorbach, 2008) or 'wicked' (Voss & Kemp, 2005) problems in the sense that failures cannot be corrected by the market without external influence. They are inherently difficult to manage and involve a number of different actors with a range of interests. In order to solve these problems, innovative societal governance structures along with policy mechanisms would need to be formed, requiring the restructuring of the system's operational properties (Verbong & Loorbach 2012).

The 'persistent problems' discussion often revolves around a single issue which is deeply embedded in societal structures. For the case of the electricity system there are three interlinked problems identified by Government (climate change, energy security and affordability). Each of which will need to be overcome collectively, making the issue far more complex. In addition to this the electricity system has multiple future changes that will need to be complied with (such as the electrification of heat and transport). This would mean that in attempting to transform the energy system, the governance challenge becomes more demanding and ambitious (Smith et al., 2005).

The current electricity generation mix will not be able to meet the targets and goals which have been set out to combat the 'persistent problems' (see chapter 2). This thesis is examining the possible impact of changing this centralised approach to a decentralised operation in order to meet these goals, specifically focussing the discussion on energy security and the governance implications.

It is likely that both a centralised and decentralised electricity system will be able to meet the goals set out by Government. The move to a new electricity future will inevitably require large sums of money; the current infrastructure requires renewal and expansion involving huge financial injections (Gil and Beckman, 2009; UNEP, 2011; Markard et al., 2012). Technological and economic modelling used in Government and other institutions are now the main tools in energy pathway analysis (Foxon et al., 2011). This economic analysis focuses on the visible impacts certain processes can have on the system which include: market changes, profitability, contracts, regulations and standards, also skills and knowledge. Economics plays a major role in policy making and therefore the future direction of energy system development. However, the result of this purely economic model is that many of the implications for the broader socio-technical impacts could end up being neglected (Strachan and Warren, 2011).

Academic approaches to systemic change are currently developing along a route which explicitly builds in these broader socio-technical aspects, and some of these are set out in the following sections. An increasingly influential model of socio-technical transitions described by Frank Geels and other researchers is set out below.

6.2.2 What is a Socio-technical Transition?

Sectors such as the electricity industry are made up of networks of actors (individuals, firms, and other organisations) and institutions (societal and technical norms, regulations, standards of good practice), as well as material artefacts and knowledge (Geels, 2004; 2011; Markard, 2011; Weber, 2003). The way in which these dimensions interact form the specific services for society and can be conceptualised as socio-technical systems (Markard et al., 2012).

Transitions are radical shifts from one system configuration to another at the macro scale and over a long period of time (Verbong & Loorbach 2012). The changes include technological, material, organisational, institutional, political, economic and socio-cultural movements. This complexity provides a distinction between a socio-technical transition and what could simply be defined as an incremental change (Roggema et al., 2012). According to Grin et al (2010) transitions require multiple changes, involving a large variety of actor groups.

The main driving force of a sustainable transition is the design of guidance or governance (Smith et al., 2005 Markard et al., 2012). The intention of shifting to a low carbon system means that the required transition is purposeful and intended, meaning a range of actors will work together for a defined outcome (Markard et al., 2012), rather than an accidental outcome of system development. However, even though the final goal (a low carbon system) is agreed, the different actors (or networks of actors) may pursue different pathways in order to achieve this goal (Meadowcroft, 2011).

Using the UK Government's low carbon objectives as an example, the short-term impact of moving to a low carbon electricity system may require a large injection of investment (Ofgem, 2010a). However, with a competitive market place, energy companies may find it more profitable to remain on the current 'business as usual' pathway and not invest in low carbon technologies. This means that external guidance is required in the form of either incentives or penalties to incentivise investment in desirable options.

6.2.3 Examining system transitions

There is a growing body of research which is designed to analyse the transitions of different sociotechnical systems. The complexity and multifaceted nature of a socio-technical system means that there are a number of different approaches that have been set out in the literature, each of which focuses on slightly different aspects of systemic change which can be made. This thesis will identify the main theories relevant to the subject.

Transition management is based on the idea that transitions can be influenced and guided (Kemp and Loorbach, 2006; Loorbach, 2010, Markard et al., 2012). The main principles of transition management are that the systems are complex but still have the ability to be adapted and the transition process is one of evolutionary governance over a period of time (Nill and Kemp, 2009; Voß et al., 2009). The biggest challenge transition management faces is that it tries to translate the abstract theoretical dynamics of transitions into a practical management framework (Rotmans and Loorbach; 2008). It is designed to create space for the system players, whether they are niche or regime players, to form coalitions, which can put pressure on regular policy. While transition management focuses on broad systemic issues, strategic niche management adopts a more 'bottom-up' perspective, investigating and directing how niches grow, stabilise, or decline (Raven, 2006). The niche is a conceptual technology through which an innovation can develop away from the influence of the system's structures (Foxon, et al., 2009). Over time they gain enough momentum in order to establish themselves within the recognised technologies (Kemp et al., 1988; Smith, 2007; Markard et al., 2012).

Both transition management and strategic niche management were developed with the intention of providing a policy roadmap to ease purposive transitions. Similarly, the technological innovation system approach grew out of the policy debate about barriers and drivers for innovation (Bergek and Jacobsson, 2003; Jacobsson and Bergek, 2004; Jacobsson and Lauber, 2006; Negro and Hekkert, 2008). The focus of this analysis is on the changes to the technological landscape and institutional and organisational changes, which coincide with development.

Each of these approaches provide analysis of a transition, however, the approaches are of limited usefulness in the context of this thesis because of the multifaceted nature of the electricity system, which is being analysed. The electricity system requires an approach, which also incorporates a multifaceted analysis of any transition to include each dimension associated with moving to a low carbon electricity system. In addition to this the transition needs to incorporate a coevolutionary element, where by the changes which occur in one dimension would need to coincide with all dimensions (Kallis and Norgaard, 2010). What this also means is the coevolution cannot be a barrier to the transition to a low carbon electricity system. The coevolution of technologies and institutions is argued to promote lock-in of current high-carbon technological systems (Foxon, 2010). This argument can also be transferred to the lock-in of centralised electricity generation and delivery identified in this thesis.

This thesis has identified the multi-level perspective (MLP), which provides a framework for understanding the intricacy associated with socio-technical systems (Rip and Kemp, 1998; Geels, 2002; 2004; Geels and Schot, 2007; Markard & Truffer, 2008). The MLP approach utilises a holistic methodology for analysing a transition, looking at all aspects which the move from a large-scale centralised system to decentralised system may involve.

Geels (2010) sets out three different dimensions which influence system development and transition (see Figure 6-1). The socio-technical landscape is the wider context of the system; it provides the environment within which the regime dynamics are influenced and consists of macro level factors such as political ideologies, or in the context of current system change, the growing understanding of the impacts of climate change. (Rip and Kemp, 1998, Verbong & Loorbach 2012). The landscape usually changes slowly, as the actors in the regime and niche level have very little influence over its development. Landscape factors have the ability to put pressure on dominant regimes (Raven et al., 2012; Holtz, 2012). The strength of the landscape factors can impact on the speed of which change may occur (Kern, 2012). Furthermore, these factors can evolve over time and destabilise the existing regime enabling any lock-in to be broken (Shackley and Green, 2007).

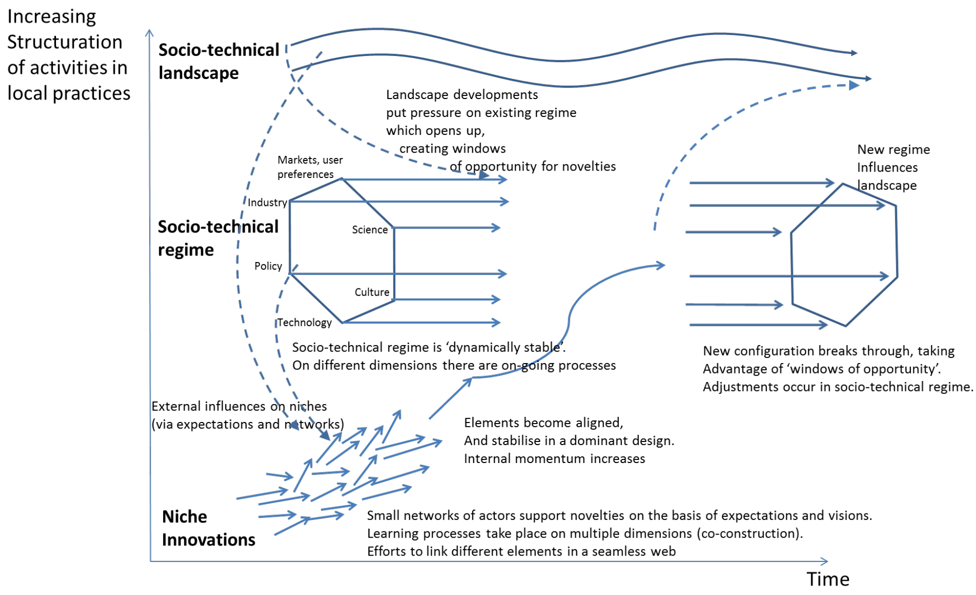

Figure 6-1 Multi-level perspectives on transitions (Geels, 2011)

The meso-level socio-technical regime consists of the dominant rules and policies, which are supported by the networks of actors and the infrastructure which comes with them (Jørgensen, 2012). The nature of a stable regime means that it is locked-in and innovation would only occur incrementally. These changes occur not only in technology but in the policy, society, market and scientific regimes which are all interconnected through the multifaceted nature of the electricity system. The incremental process of change across these dimensions is shown graphically in Figure 6-2 (Geels, 2011).

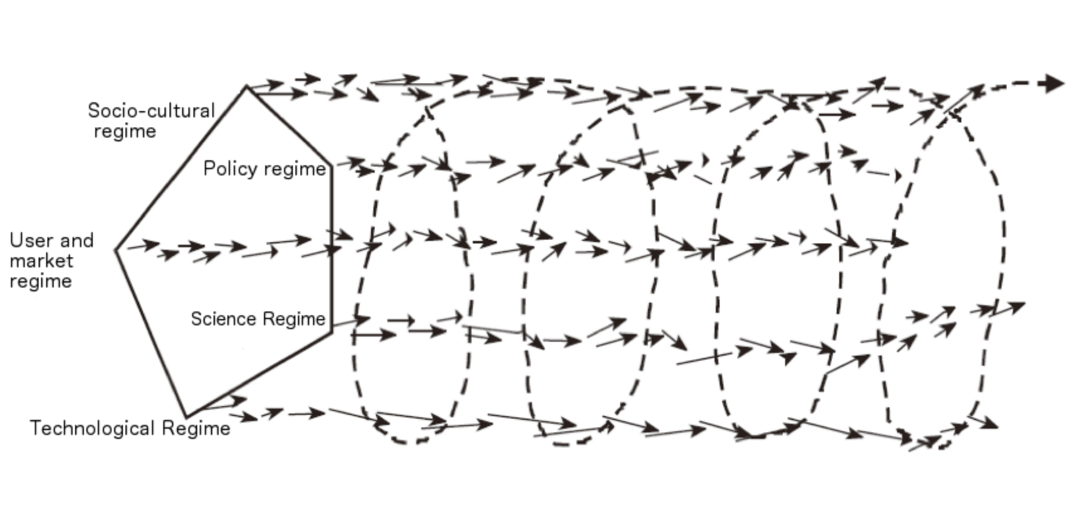

Figure 6-2 Alignment of on-going processes in a socio-technical regime (Geels, 2011)

Finally, at the micro level, niches are defined as small, protected spaces, in which innovation can develop away from harsh selection criteria and the dominance of prevailing regimes. They can include the research and development (R&D) laboratories, demonstration projects or small market openings where users require specific innovations. The niche actor works outside the existing regime, hoping that it will be able to 'break-through' and provide a seed for systemic change (Schot et al., 1994; Kemp et al., 1998; Geels, 2002; 2010; 2011; Hoogama et al., 2002; Smith and Raven, 2012).

6.2.3.1 MLP in the electricity system

This section will examine the use of MLP in the electricity system focussing on the transition from a centralised electricity system to one, which is highly decentralised. The move to a decentralised electricity system will likely involve changes to the whole electricity system, MLP theory incorporates a holistic overview focussing on the macro (landscape), meso (regime level), and micro (niche) dimensions.

In the electricity system the landscape factors can be considered as the challenges set out by Government: carbon reduction, energy security and affordability. Each of these landscape factors are not specific to the electricity system and therefore may not be solved by an electricity system transition. However, the electricity system has a large impact on these challenges and therefore the Government has placed an impetus for the system to adapt in order to meet them.

The factors making up a socio technical regime (Figure 6-2) include: the socio-cultural, policy, science, user and market, and technological. For the electricity system, these can be considered as the stakeholder groups (such as the energy companies, Government, regulators, network companies and consumers) as well as the rules and incentives (including the Government and company policy, market arrangements and subsidies) (Rotmans and Kemp, 2001; Smith et al., 2005). The regime could be considered as the governance of the electricity system (which will be discussed in the section 6.3); it helps structure the interaction of stakeholders and the rules of the system. The rules are not there to solely constrain the actor but they also enable actors and actor networks (Geels and Schot, 2007).

The UK electricity system is dominated by centralised generation. This centralised domination can be argued as being the result of market structure and ownership which is strengthened by the investment into centralised technology and infrastructure (van der Vleuten & Raven; 2006).

It is also argued that overcoming this lock-in to a centralised system is a significant barrier to the deployment of small-scale technologies. Therefore, an evaluation of the Government factors which may provide such a change is required.

The niche dimension within the move from a centralised to a decentralised electricity system could also play a much larger role, as the process introduces a number of smaller actors working outside the marketplace trying to break into the current system. However, the current position of small-scale technology specifically solar PV is that it is beginning to move from the niche to the regime (with the help of mechanisms as discussed in section 2.5.4). This is indicated in Figure 6-3 with the sharp rise in small-scale capacity from July 2011 to April 2013 (DECC, 2013c).

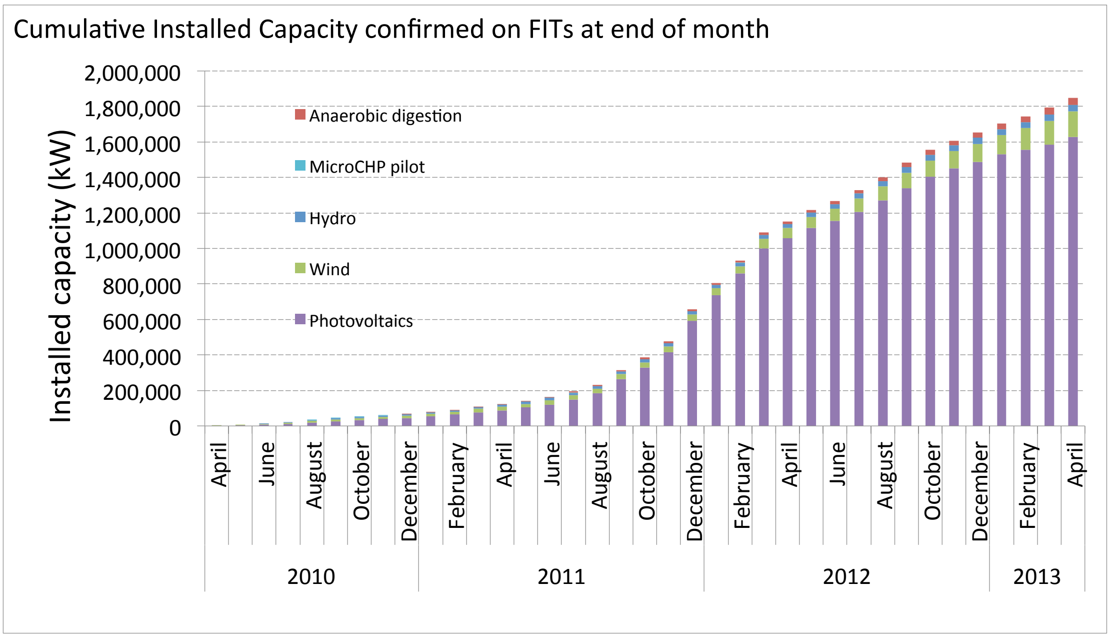

Figure 6-3 Cumulative Installed Capacity confirmed on FITs at end of month (DECC, 2013c)

6.2.3.2 Low Carbon Future Pathways

Targets and goals set out by Government provide an opportunity for increased levels of decentralised and renewable generation. However, other pathways are also available such as the move to low carbon nuclear and fossil fuel with carbon capture and storage technologies (Vergragt, 2012). The MLP approach can be used to represent these two different pathways to meet a centralised or a decentralised future. Figure 6-4 is a representation of the MLP approach where these two possible futures are identified (Verbong & Loorbach 2012). However, the reality is that it will be unlikely for a purely centralised or purely decentralised electricity system to exist, meaning there would be an amalgamation of these futures. The question is not how specific barriers can be removed or what possible incentives are available, but how the electricity system can be guided in the desired direction.

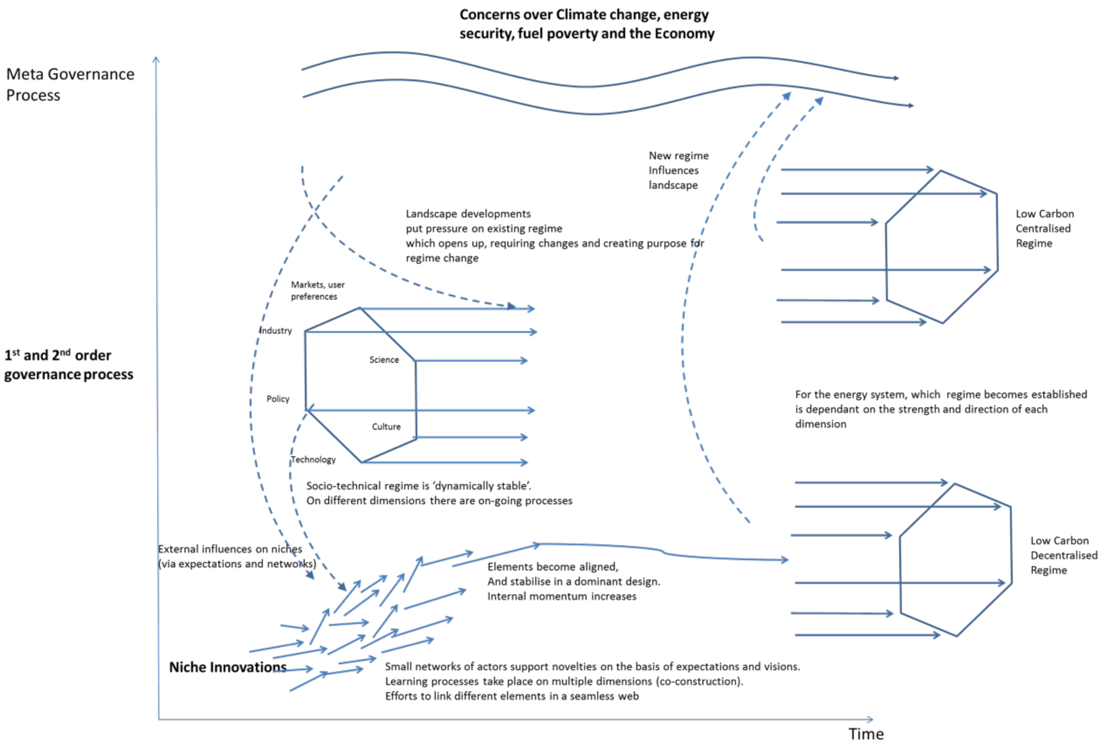

Figure 6-4 Bi-Polar view on a transition to low carbon; centralisation or decentralisation. Adapted from (Verbong & Loorbach 2012) depicting the Multi Layer Perspective approach to transitioning to a low carbon energy system.

6.2.3.3 Critique of MLP

The MLP can provide a useful framework for analysing the transition of the current electricity system to a low carbon, secure and affordable future. The use of MLP as a framework for analysing transitions has been critiqued and reviewed within academic literature. Therefore, this section will identify the main criticisms of the MLP framework, which may be relevant to its use with the electricity system

The first criticism is its lack of consideration of agency (Smith et al., 2005; Genus & Cole, 2008). The MLP does little to account for the role of power and politics in its analysis. Genus & Cole (2008) suggest that the MLP analysis would need to be integrated with some form of actor network theory in order to include the role and networks of actors within the model. In contrast to this, Shove and Walker (2010) criticise the idea of different levels of power and place an emphasis on the latter viewpoint, using multiple relations over a range of scales rather than levels. In order to tackle this criticism this thesis will address the role of actors and the influence of power in chapter 10, discussing the use of governance to establish a regime and the different methodologies of understanding governance.

Another criticism of the MLP framework is the use of regimes as a specific dimension, meaning the theory could be discussed at different scales and levels possibly changing the final outcome (Berkhout et al. 2004). An example of this is with the electricity system. A study can be made of the way in which electricity is transported using transmission and distribution networks, or it can look at the system as a whole considering the production transportation and consumption of electricity. Therefore, what is seen as a regime change at one level could be viewed as an incremental change at another (Geels, 2011). This criticism has been addressed as this thesis has defined what is meant by a decentralised electricity system (see chapter 5) setting the parameters of what is being discussed.

The MLP has also been criticised for its predisposition to discuss the use of niches as the catalyst for a regime change. This emphasis on bottom up system dynamics removes itself from systems which are directly addressing the dimensions of the regime in order to enact change (Berkhout et al. 2004). While the critique is valuable in developing the MLP approach, it is not specifically relevant to this research because the move to a decentralised electricity system denotes an increase in small-scale stakeholders becoming involved thus introducing a larger number of possible niche players. In addition, the small-scale renewable technology of a decentralised system could currently be considered as niche technologies; as they would be unlikely to be operational in the current market place without the subsidies developed from the landscape issues.

The MLP approach does make an attempt to discuss the various perspectives of a system by looking at the niche, regime and the overarching landscape. However, the discussion over the impact of governance on the system with this approach is limited. The inclusion of governance analysis alongside the use of MLP will help provide a broader understanding of the move to a low carbon electricity system whilst answering some of the criticisms of MLP identified above.

Smith et al. (2005) and Genus & Cole (2008) both identified MLP as having a lack of agency and no development of the position of the roles and perceived power of each stakeholder group. By introducing an aspect of governance not only will the roles and responsibilities of each stakeholder group be analysed but also their interactions. It is these interactions which generate the rules and incentives that direct the actions of these stakeholders.

In addition to this the regime aspect of MLP which includes the socio-cultural, policy, science, user and market, and technological dimensions. The use of governance goes further to develop these aspects and understand how the regime aspect develops an electricity system. This develops the issues for MLP theory Berkhout et al. (2004) identified; that MLP has a predisposition to discuss the use of niches as the catalyst for a regime change. By developing the governance aspect there is a better understanding of how a regime develops the electricity system. Therefore, this thesis will now discuss the impact of governance on the electricity system.

6.3 Governance

This section will begin by outlining a definition of, and then look at, the current literature on governance including the classical and modern theories, using these theories to provide a specific definition of governance for this thesis. It will then apply this to the electricity system and develop the understanding of the relationships, roles and responsibilities of the electricity system stakeholders.

The concept of governance is rarely defined in a clear manner; in general it consists of the collective decision making of actors and the rules that follow them (Chhotray and Stoker, 2009). Some definitions attempt to define governance as the "activities of social, political and administrative actors that can be seen as purposeful efforts to guide, steer, control or manage (sectors or facets of) society" (Kooiman, 1993, p.2). This definition considers the impact of society as a dimension to be governed; it still looks at governance as a one-way entity, with a top down overview of how certain groups impact on society. Any changes to governance would involve changes to institutions and actors both governmental and non-governmental (Kjaer 2004). This means that new policies and mechanisms may require new institutions such as the introduction of the CfDs and the creating of the Low Carbon Contracts Company to deal with them. Another example is the creation of the Feed in Tariffs which has lead to an increase in the number of smaller energy stakeholders from households to community groups and businesses.

Parag and Janda (2010) argue that what is needed, in addition to a bottom up approach, is a middle out look at how stakeholder policies and rules interact. This is because the governance of the energy system does not simply rest on a single set of stakeholders or actors. Therefore the definition of governance needs to take into account all of the players, their interactions and associated power.

The concept of governance has recently become more widely discussed in the social sciences and in the policy world. Its popularity has generated many different meanings and for the purpose of this thesis it is important to clarify the understanding of these different approaches (Kooiman and Jentoft, 2009). Stoker (1998) provides a number of aspects of governance for consideration, each of which discuss governance as a set of institutions and actors drawn from within and outside government. Each of these groups have overlapping responsibilities within the system meaning that the power of each actor is a result of the networks which have formed and their collective action. Here, governance is discussed as self-governing networks with the capacity to get things done, rather than the hierarchical powers dictating or using authority to steer the system (Smith, 2007). The approach with which governance is viewed within a particular system can orientate how a system progresses.

For the purpose of this thesis governance is defined with two interlinked aspects; the organisation of stakeholders within the electricity system as well as the rules and incentives which enable the system to achieve the desired outcome. The basis behind this definition is set out in the next few sections.

This concept of governance categorises the energy system into interacting groups of actors constrained within a sector. For this thesis, an electricity system actor is defined as any individual or collective of players within the electricity system whose behaviour impacts on the system. An example of this is the individual household consumer; currently seen as having only minimal engagement with energy system operators (DECC, 2011f). Consumers as a group however, have the ability to have a large impact on the electricity system through the decisions they make in terms of the energy company they buy their electricity from and their demand behaviour.

The term stakeholder is relative to the issue; it is time and site specific, which means a stakeholder's relevance may change over time and between issues. A stakeholder can be considered as anyone who possesses the power of action and the desire to use it (Glitchen, 2000; Kooiman and Jentoft, 2009). These can range from Government, to the energy companies operating within the electricity system. If the individual household consumer decided to invest in a small-scale generating technology this action would denote a desire to be involved and they could then be viewed as a stakeholder.

The rules and incentives are the cognitive routines and shared beliefs, capabilities and competences, lifestyles and user practices, favourable institutional arrangements and regulations, and legally binding contracts which relate in the electricity system (Geels, 2011). The rules and incentives that are shaped by the stakeholders, also have a role in shaping the stakeholders, making governance a fluid concept.

The need for governance, in a competitive market-based system, can be explained in part by the failure of the markets to provide a desired outcome. This is because the incentives of producers and consumers may be misaligned, requiring strategic planning over the whole system (Florini and Sovacool, 2009). An example of this is in the current electricity system where the market would be unlikely to provide the low carbon future required to reduce the impacts of climate change (DECC, 2012n). The electricity system is complex; wholesale electricity exchange is operated through the markets, but the distribution and transmission networks are regulated monopolies. This requires a multi-faceted understanding of governance for the electricity system, where different approaches are used.

6.3.1 Governance Theory

Differing governance processes can affect how a system develops. Electricity system stakeholders have a range of motivations, which can influence their actions internally and externally. Internal motivations are developed from the values they hold, the resources they command and the strategies they choose to follow. External motivations can include the national policies, market rules, and regulatory structure (Foxon et al., 2009). Therefore, it is important to understand the relationships between actors as well as the rules and incentives in order for policy makers to find the optimal solution for the system but also identify how change can occur. This thesis has identified the different rules and incentives for market and regulatory frameworks in (chapter 3). It will look at the relationships of actors in (section 6.3).

This section will begin by looking at the background behind governance theories, it will then look at the classical governance, structural governance, the ranking of governance and finally it will provide an overview of modern governance approaches.

6.3.1.1 Approaches to understanding governance

The **classical** theories of the governance often cover the extent to which societal change occurs as a result of the actions and policies of government (Rhodes, 2007; Rotmans and Loorbach, 2008; Pahl-Wostl, 2009). However, government is merely a single group of actors who have the ability to influence a system. Historically, academic research has focused on the policies and actions of governments, but more recently they have started to address governance outside governmental structures at a variety of scales, from large market players to the smaller individual consumer. This thesis will look beyond governance as government and use the assumption that societies are governed by the efforts of a number of actors and entities made up of both public and non-public groups (Kooiman 2003; Rotmans and Loorbach, 2008).

The **structural approach** provides three dimensions to organising the stakeholders and their interactions. The interactions are defined as: hierarchical governance, self-governance and co-governance. For hierarchal governance, the most common example is the interaction between the state and other actors. However, more recently the perceptions of hierarchical governance show the commanding state as a regulatory one, delivering structure through the market and activating other roles. The control and steering of the system is key to forming a hierarchal structure (van Dijk and Winters-van Beek, 2008; Never, 2011). In the self-governance mode, the stakeholders take care of themselves. This occurs away from state control, and control is not achieved through government policy; it occurs naturally of its own accord. The concept of co-governance looks at the networks of different actor groups with a common goal or ideology. Co-governance can include the idea of public-private partnerships and co-management of infrastructure (Kooiman and Jentoft, 2009). In practice, societies are governed through a mixture of these three modes (Kooiman and Jentoft, 2009).

Governance ranking is closely related to the structural approach, however, it is different in that it attempts to identify the power of each stakeholder rather than the interactions of stakeholders. Governance ranking considers the ranking of governance activity in three different terms: first order, second order and meta governance (Kooiman and Jentoft, 2009). First order governance deals with the day to day affairs considered to be in the 'outer ring' of governance. In this situation problems are identified and solutions enacted. This is done through the state organisations and system actors. Second order governance focuses on the institutional arrangements where the first order governance takes place. These arrangements include the rules, incentives and mechanisms. Meta governance can be considered as the governing of governance, it surrounds the debate on the underlying principles such as sustainability, the economy and energy security (Kooiman, 2003; 2008). There are no clear boundaries where meta governance takes place, rather it is simply the principles which shape the structure of the governing process. Examples of this include the codes of conduct at international level and media focus on specific issues such as the impact climate change has made through media discussions and its effect on society (Evans, 2012). However, constraining the theoretical approach to government and markets alone would denote a limited impact from other stakeholders and not provide a complete picture of the energy system (Smith, 2007).

More recently a new set of theoretical approaches have come to the fore in an attempt to find a more complete understanding of how the system operates. These modern approaches to governance places a greater emphasis on the range of stakeholders who are involved in a particular system and does not fixate on Government as the main governance player. Some of these are outlined below.

The **Network Approach** describes society as a complex network of actors and stakeholders (Peterson, 2003). Networks can be formal or informal, with the actors having the same vested interests, these interests can be better achieved as a group rather than individually. This approach to governance does not use the formal discussion of governments being a hierarchical power, instead it uses the idea that a network of stakeholders can have the necessary means and incentive to drive the system. This approach follows on to **The Policy network approach,** which, is designed to examine the outcomes of policy decisions, analysing a cluster of actors each with a given stake or interest and the ability to determine policy success or failure (Rhodes, 1997; Marsh and Smith 2000; Peterson, 2003). The use of policy networks, however, can be critiqued in three main areas. The first critique is the lack of model and primary theory. It is often seen as a useful metaphor and does not go into any depth to explain the dependency of actors and how their dependency is restricted. Nor does it provide any testable hypothesis for the importance of networks in decision making (König, 1998). The second critique is that the natural fluidity of policy making means there is little chance for stable networks to exist. Stakeholders form alliances around specific issues creating 'issue networks' (Marsh and Rhodes, 1992). However, because of the promiscuity of the stakeholders, networks can quickly disintegrate (Kassim, 1993). The changing agendas of stakeholders means that they automatically alter networks and create complexity in the coalitions formed (Thatcher, 1998; Richardson, 2000). The third critique is that the network analysis does not take into account any theory surrounding power (Peterson, 2003). Dowding (1994) shows the need for network analysis to be supported by a general theory of policy process defining a theory of power (Owen, 1995).

The Interactive Approach discusses government actors working closely with actor networks and stimulating them through targeted incentives such as goals to be met or subsidies for a particular technology. This means that policy outcomes are not directed by central government. Central government may enact policies and policy mechanisms, and pass laws but it is their interaction with stakeholder groups and their interaction with each other which defines the outcome (Rhodes, 1996; 2007). One of the key issues with an interactive based approach is that it is seen as a micro level analysis of social relations and can often lead to 'cherry picking' on behalf of the decision makers (Kooiman, 2003; Edelenbos, 2005).

The **Multi-level Governance** examines the interface and developments at different levels of organisation, each of which require different strategies. At each level the participants have specific policy instruments in order for them to work toward the same goal (Smith, 2007). It does not reject the idea that state is important or could be the most important stakeholder in a sector, it identifies that the state does not monopolise the policy and decision making process. Multi-level Governance theory, can therefore be seen as a substitute for hierarchical governance by government (Marks et al., 1996). However, it can also be discussed as policy networks, which are 'nested' in Government institutions (Peters and Pierre 2000).

The final approach is **Social Learning**, which is aimed at changing the perceptions of the actors involved. This process has three dimensions: learning by doing, doing by learning, and learning by learning, each of which discusses a different aspect on how society changes its ideas. In the case of moving to a decentralised electricity system a high level of individual householder engagement may be required (Carbon Trust, 2013). This is because much of the investment will come from additional sources such as community groups and individuals. Through economic incentives consumers begin to introduce themselves to the energy system; they become invested in the policy and decision making which occurs, changing the social understanding and overall level of knowledge which is held by this group of actors (Rotmans and Loorbach, 2008).

It is important to understand these approaches to governance as these are often used to analyse current policy and to discuss the makeup of a specific system such as the electricity sector. Each of these approaches identifies a specific aspect of governance theory as a means to analyse either previous governance processes or as a forward looking approach to driving change in a system such as the electricity sector. For the purpose of this thesis however, a definition which can be used to discuss the overall governance of the electricity sector is required. It is also needed to be relevant when discussing a centralised or decentralised electricity system. Therefore, as identified in section 6.3 this thesis defines governance with two interlinked aspects; the organisation of stakeholders within the electricity system as well as the rules and incentives which enable the system to achieve the desired outcome.

The interaction between stakeholders may form coalitions with groups which have the same desired outcome or the need to share resources and responsibilities. These networks may not be directly accountable to the state, and are self-organising. They can, however, indirectly steer the networks (Rhodes, 2007).

The rules and incentives can be defined as the detailed policies, which are implemented, and the mechanisms designed to achieve the desired outcomes. These processes are obviously created and dictated by the networks of stakeholders but they also go some way to forcing the organisation of the networks, thus making them co-dependant.

This thesis will use this definition to review the governance processes of the UK electricity sector.

6.3.2 Governance of the UK Electricity Sector

Following on from the discussion of networks in the previous section, the relationships of the various actors provide the overall governance of the electricity system. This thesis will separate the actors involved in the energy system into four groups: government lead actors, regulatory bodies, market led actors (such as the large supply companies and development industry) and civil society, which include the ‘end users’ but also organised communities and media bodies (SDC, 2007; Foxon et al., 2009; Parag and Darby 2009). This is a simplification because, in reality, actors cannot be so clearly categorised; they can differ in their opinion over the energy domain and may also be considered a part of more than one category

(Parag and Darby 2009). However, by examining them in the four groups this thesis will be able to evaluate the nexus of power between these four groups, and provide an explanation of how different governance systems can operate. This section will discuss the interactions between the different actor groups and the implications of the hierarchical structure in order to review the current electricity system approach and the possible future outcomes.

6.3.2.1 Actor Relationships and the Balance of Power

The interactions between the different stakeholder groups provide the basis for the rules and regulations of the electricity system (Goldthau and Witte, 2010). Both Foxon et al (2009) and Parag and Darby (2009) demonstrate the relationship between government, civil society, the market players as a triadic relationship.

Foxon et al (2009) analyse governance patterns for transition pathways for a low carbon future in the UK. The paper explores the different governance patterns, which relate to central government, market actors and structures, and civil society. Foxon et al., identifies the governance of the UK energy system as a way of affecting the technological institutional and social change. They discuss the governance patterns as the relationship (the balance and mix of actions) between central government, actors in liberalized markets and civil society actors (Figure 6-5). Within this, government led actors include government departments, advisory and regulatory bodies and the legislation they create. Market led actors cover the vertically integrated supply companies and the smaller market-based actors. The civil society led actors include end users, trade unions, media and organized environmental movements.

Foxon et al go on to discuss the relationship of power between each of these actor groups and how they may differ. From this they identify 'action spaces' which are created by the actor groups and define the energy regime. These action spaces change depending on which actor has the greatest power, ultimately providing a framework with which to understand and conceptualise the existing energy system. This thesis will discuss the relationships of power between the actor groups who have a significant role in the security of the electricity system later in this section.

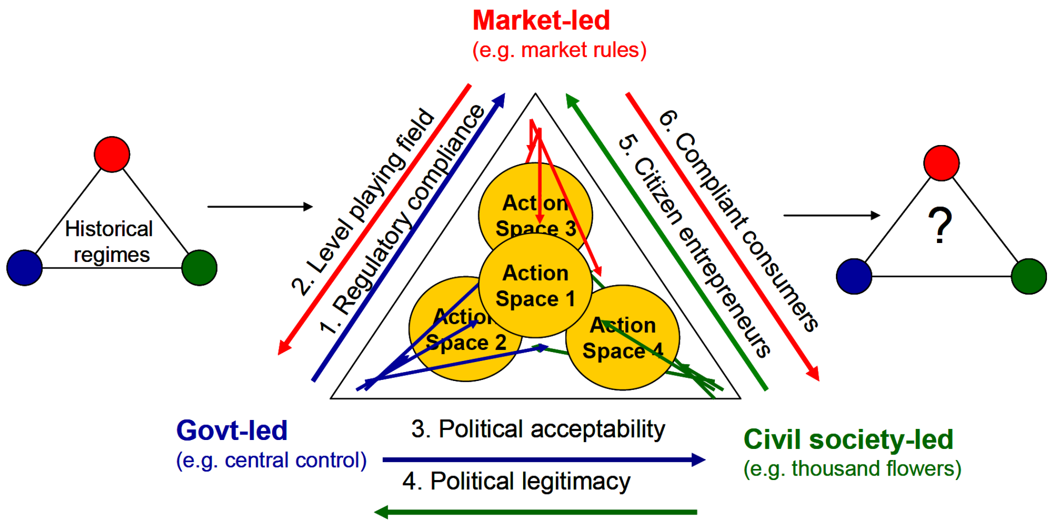

Figure 6-5 Action space for transition pathways (Foxon et al., 2009)

Parag and Darby (2009) have developed a similar approach to examine the main groups of actors involved in reducing carbon emissions. Although the focus of Parag and Darby's work was on the UK residential householder they utilise a framework which can be related to Foxon et al., discussing a low carbon future for the UK energy sector. Parag and Darby examine the governance of emissions reduction, including how the policies are shaped through the relationships between the main groups of actors in this area: central government, gas and electricity suppliers and energy users. They also discuss the interrelationship between these three actor groups through their aspirations, regulations, actions and transactions. These relationships are identified in Figure 6-6.

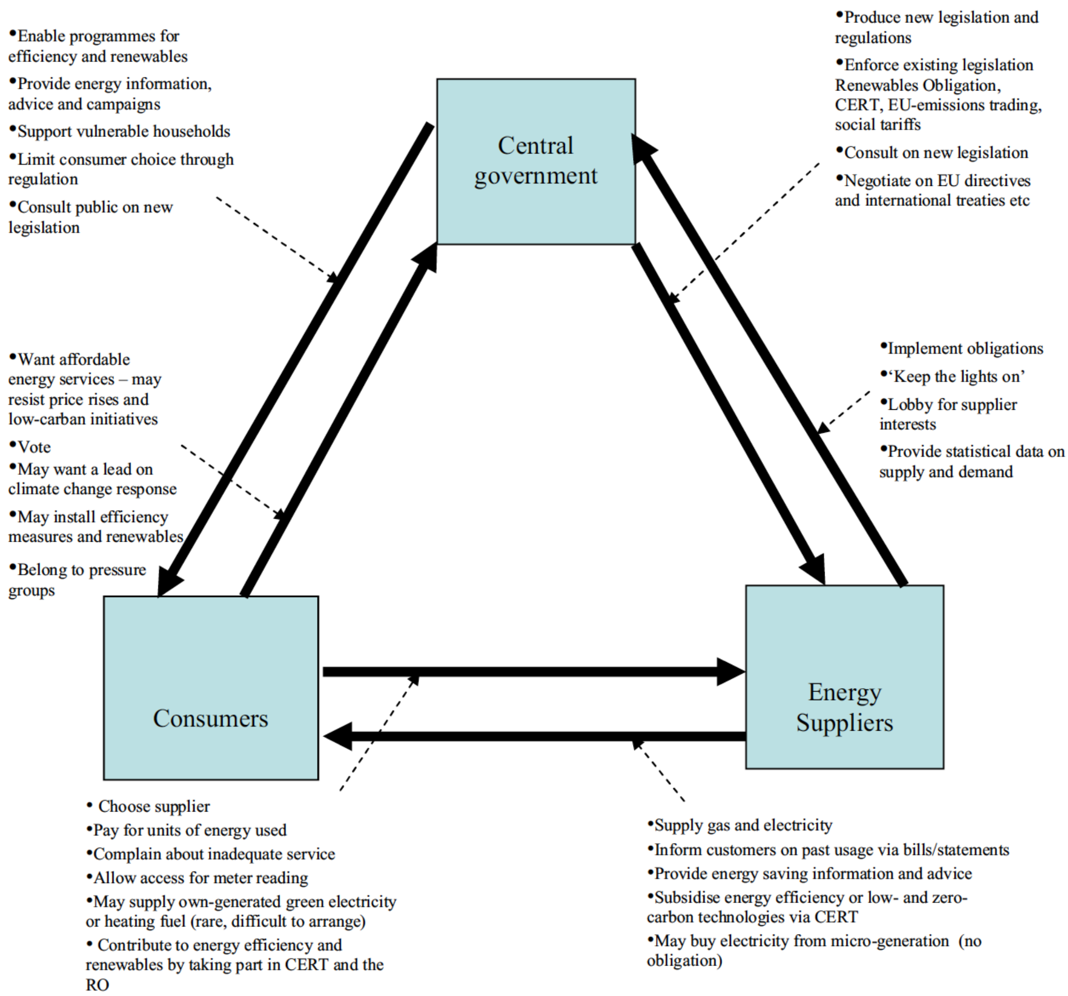

Figure 6-6 Main groups of actors in attempts to reduce carbon emissions from household energy demand: actions, communications and expectations (Parag and Darby, 2009)

Structuring the energy system into these three categories, as both Foxon et al and Parag and Darby have done, does not provide the full picture of the relationships and actions of the system actors for energy security. In reality categorising actor groups is far more complex; each actor will be likely to have different aspirations on the future of the energy system thereby not fitting neatly into one category. However, it is useful to group them in this way as it removes much of the complexity in order to illustrate the governance of the energy system.

This thesis will add a fourth dimension to this triadic relationship, not identified by the previous authors; Regulatory Based Stakeholders. Regulatory Based Stakeholders include the distribution and transmission network operators, which do not fit into the current three categories. Both Foxon et al and Parag and Darby identify Ofgem as a part of the Government group[24], however, they do not include Regulatory Based Stakeholder as an aspect of the research. This may be because they were not seen as a fundamental aspect of a transition (Foxon et al) or for the reduction of carbon emissions (Parag and Darby).

For this thesis the network operators are considered to play a major role in the security of the electricity system, especially in a low carbon future. These Regulatory Based Stakeholders not only provide day to day delivery of electricity (and therefore security of supply), but they also have a role in the future of the electricity networks through the smart grid development and their ability to accept a greater level of low carbon electricity generation on the networks. This new framework is shown in Figure 6-7.

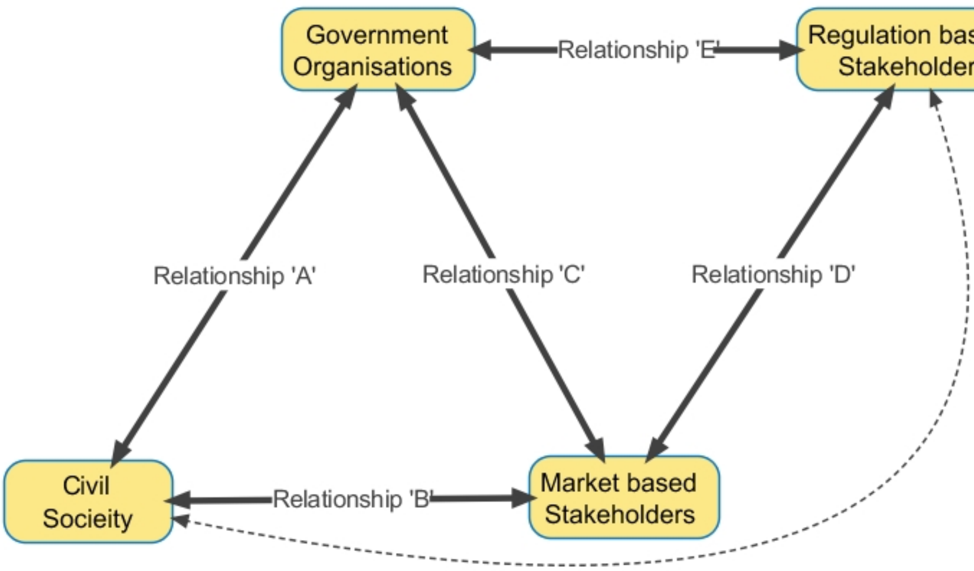

Figure 6-7 Main groups of actors involved with the governance of energy security (adapted from Parag and Darby, 2009; Foxon et al 2009).

This thesis argues that the relationship between actors and actor groups can be dictated by their perceived power and therefore needs to be taken into account in any governance approach (Berger, 2003). The power of an actor is defined by their ability and desire to drive change (Preble, 2005). This power can be provided by their size in terms of numbers or wealth and the policies and mechanisms they have access to (Scrase et al., 2009). However, power may not be seen as a one-way concept with one actor dominating over another. Rhodes (1997) suggests that

24 Although Ofgem is directly a part of central Government it does have strong ties and links to them. Therefore, it is useful to include them in this category rather than creating further complexity.

power should be understood as an exchange relationship where one actor will need the other. For example the Government need the Energy companies to provide information and to implement the policies, the energy companies need Government to promote their interests (Richards and Smith, 2002).

> *"organisations depend on each other for resources and, therefore, entre exchange relationships"(Rhodes, 1997 pg: 9)*

Figure 6-7 looks at the interaction of stakeholders and will be discussed in terms of ensuring a secure energy system. The model is a simplified representation of the relationships which are apparent in the electricity system. Within each stakeholder group there would be a number of sub-groups, each of which would have a variety of requirements for the future. Although this matrix would be interesting to explore beyond the boundaries of this thesis, viewing the relationships and the interplay between each group provides an insight into how the different pathways might play out within the current electricity system and how different actors may be likely to react to changes such as an increase in decentralised energy (Foxon et al., 2009).

6.3.2.2 Actor Responsibility and Power

The responsibility of a stakeholder for a specific aspect of a system can be identified in legislation, which can also set out their ability to achieve this. For the purpose of this research, responsibility will be considered as an actor, or group of actors, who have the ability and obligation to act. This means that the level of power an actor holds can have an impact on their responsibility (i.e. low power, low responsibility and vice versa). An example of this is the system operator's responsibility to ensure the electricity system balancing, achieved through the balancing and settlement code (BSC). However, defining responsibility for a wider issue such as energy security which can encompass a range of policies is not easy. What can be identified is that responsibility is set out by the legislation and the stakeholder's power to fulfil that legislation.

The issue with energy security is that the Government who determine policy and have priority "deliver secure energy on the way to a low carbon energy future" (DECC, 2012d pg.: 2) are often considered as responsible for energy security of the system as a whole. However, this may not be the case. For the energy system the Government has partly conflicting policies of carbon reduction, energy security and affordability. These conflicting policies may mean energy security and affordability win out over carbon reduction.

Therefore, this Government may fall back to the pragmatic approach of delivering what the voters want. This is a very crude representation, however, it does identify that the Government only may have a short-term view point. This was also identified in the Energy Security Strategy (see section 4.1.6). As energy security requires a long-term view point (which is one of the main features which distinguishes it from security of supply) the UK Government is not the actor responsible for energy security. This is achieved through a network of actors working together. However, this network does require guidance and therefore governance. (Rhodes, 1997)

The relationship between actors and actor groups will have a direct impact on the responsibility of each actor. The multifaceted nature of delivering energy security means that pinning the responsibility on a single actor would be very difficult. In addition to this Rhodes (1997) identifies that responsibility is placed upon a range of actors:

> *"Policy is the responsibility of no one institution but emerges from the interaction of several" (Rhodes, 1998: pg. 404)*

This develops the understanding that energy security is unlikely to be the responsibility of a single institution. It will be a network of policy actors who work to provide an outcome. However, each actor does hold a level of responsibility for individual aspects which help deliver a secure energy system.

Richards and Smith (2002) identify the traditional model of responsibility as being closely tied in with the notion of hierarchy. This means that responsibility gravitates upwards, the higher the hierarchy the greater the degree of responsibility. Therefore, with this concept a defined hierarchy is required. However, the hierarchy of the electricity system could be a matter of perspective and therefore different between actors. In addition to this the complexity of the electricity system actor groups means there is a shift from hierarchy to heterarchy where all actors are engaged in policy making.

Another issue with this is that the responsibility needs to be coupled with the actors' ability to develop the energy system. This would therefore couple the actors' perceived responsibility with their perceived power and actual responsibility with actual power.

If responsibility can be viewed as an actors' perspective, then another possible approach is to view an actors' accountability. Accountability would place emphasis on a stakeholder with a specific aspect of energy security. Thereby identifying a 'weak link' and ensuring a 'system of accountability' (Rhodes, 1997) for future security. However, the issue with this is that firstly, it is a method which analyses the historic system and therefore requires any issues to occur before action i.e. it is not pre-emptive. The second issue goes back to the fact that responsibility of a policy, especially energy security, requires a range of actors working together. Therefore, it is difficult to make a system actor accountable when it would be the cause of many.

Figure 6-7 identifies the groups of actors as: Government organisations, regulatory based stakeholders, market-based stakeholders and civil society Figure 6-8 uses these actor groups and shows the type of actor relevant to each group. This section will look at the relationship between actor groups, by identifying the impacts of perceived dominance for each group. This dyadic approach to stakeholder interactions implies that their connections are separate from the rest of the sector. In reality the stakeholder groups would all operate as a network, interacting with each other. By viewing the interactions as separate entities this thesis is able to identify the overarching relationships and provide an overview of electricity governance interactions. This section will now identify the relationships and impacts of the perceived power in the actor groups shown in Figure 6-7 and Figure 6-8.

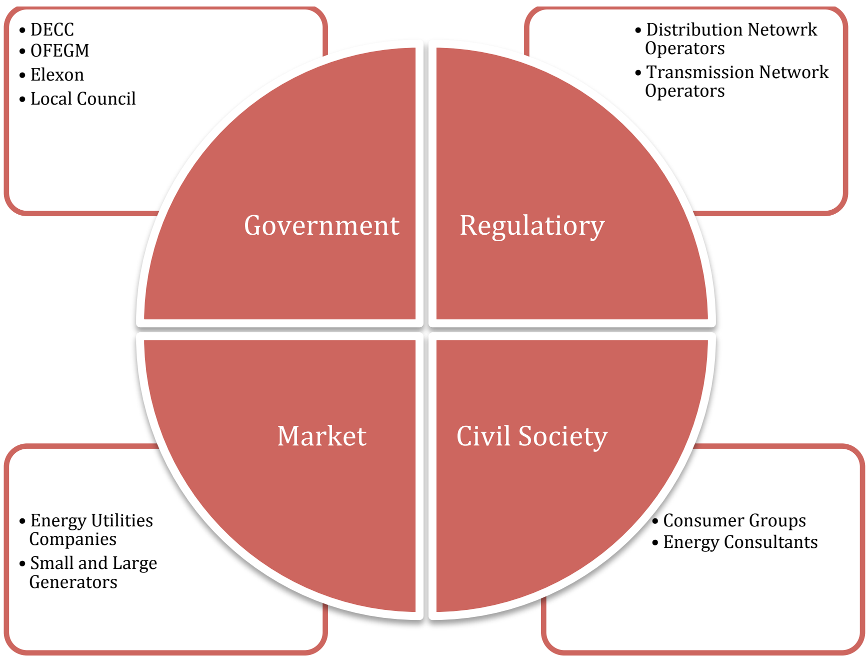

Figure 6-8 Diagram of Actor groups including type of actor group (adapted from Parag and Darby, 2009; Foxon et al 2009).

Relationship 'A' (Government Organisations – Civil Society)

The relationship between government and civil society is dynamic and complex. Government sets the rules and regulations, which are designed to provide the desired outcome (for civil society) but also to protect the consumers.

Therefore, if government is perceived as being the dominant actor group relative to civil society actors, then there may be a relationship of 'political acceptability', wherein the primary concern would be to ensure that civil society actors are sufficiently educated and 'onside' to enable policies to succeed.

If civil society actors held more power, questions of 'political legitimacy' may be posed – for example, if a government tried to impose an unpopular policy on civil society groups, questions may be asked as to the legitimacy of such decisions – protests and other forms of civil action may follow (Foxon et al., 2005).

The reality of this relationship is that the UK Government is a changing actor group. They have a four year possible change to the political party in power and intermediate changes to the secretary of state, each with different priorities for the energy system. Therefore, a government priority could be considered to stay in power, which means delivering votes. This is the longer-term view of civil society power. They also have a shorter-term impact of public action such as the protests over the building of new coal fired power stations in 2008 (Adam, 2008) and even through planning of small-scale generation. Although it could also be argued that civil society look towards Government for direction even if it is often with a small amount of distrust.

Relationship 'B' (Civil Society – Market-based Stakeholders)

The relationship between civil society and market-based stakeholders can be considered as principally related to the retail markets. In the past consumers have been accused of being very disengaged from the energy system and not looking for the cheapest energy supplier basically being content with their current long running supplier (Waddams, 2008).

For consumers it is the drive to find low cost energy generation and for the market player it is trying to find the most profitable outcome which would be the balance of raising the price of energy whilst keeping customers.

In this pairing, if civil society actors have the greatest power, a new breed of 'citizen entrepreneurs' may emerge. In this instance, citizens may become much more active in the energy system generating and exporting their own electricity, which at present utilises the market actors in order to enter the market place. But also engaging politically to ensure key planning decisions go the way they wish.

If market actors rule the regime, a dominant relationship will exist with 'compliant consumers'; the market is seen to 'know best' and consumers simply comply with the price signals sent (Foxon et al., 2005).

The reality of this is that the utility companies are dominated by the 'Big 6'. This oligopoly provides limited choice for the consumer and therefore reduced competition. As electricity is considered a necessity the consumers have little choice and require 'protection' by Ofgem from the market-based stakeholder.

Relationship 'C' (Government Organisations – Market-based Stakeholders)

The relationships between government and market-based stakeholders is probably one of the most contentious. The main conflict in this relationship is between the suppliers business objectives towards profitability (to increase market share and sell more kWh) and the Government's requirement for market-based stakeholders to help meet the targets and goals of carbon reduction, affordability and energy security (see section 2.4) (Parag and Darby, 2009).

If Government actors are deemed to have the highest relative power, then a relationship of 'regulatory compliance' may occur. In these circumstances, market actors would be expected simply to comply with government targets, posing interesting questions about how these targets are set and how achievable they may be.

If market actors are deemed most powerful, then industry representatives are likely to call 'level playing field' between the different technologies and actors. This would mean that Government would have to stay away from 'picking winners' through the specific mechanisms and subsidies (such as the FIT and RO) and it would look toward a single carbon price over the electricity system (Foxon et al 2005).

The reality in this situation is not easy to identify. The Government essentially 'holds all the cards' in determining the policy and direction of the energy system. Even though Government uses the markets as its main tool in energy security (see section 4.1 (DECC, 2012o) it also has the ability to intervene and this level of intervention is open and not set out.

Having said this the UK Government has identified the need for a large amount of investment into the energy system, part of which will be delivered by the internationally owned energy companies. Without this investment the Government could be viewed as 'driving off' the energy companies meaning they can ask for subsidies to invest in the UK.

An option the Government does have is to try and fund this investment elsewhere. In order to find large scale centralised generation there are only a limited number of stakeholders who can deliver. However, a decentralised electricity system would open the generation investment to a larger number of investors and reduce the power of a single market-based stakeholder.

Relationship 'D' (Market-based Stakeholders – Regulatory Based Stakeholders)

The relationships between market-based stakeholders and regulatory based stakeholders is one of necessity but also of relative detachment.

The governance of the electricity system is achieved though the markets and through regulation. This provides a contrast in the governance approaches between the regulation based stakeholder and that of the market stakeholder.

The link between these actor groups is one of mutual benefit; one develops a generation and consumer profile whilst the other provides the delivery and transportation of the generation to the consumer.

This means that in reality there are very little changes in balances of power between them. The DNOs are currently somewhat passive in the energy security debate and other than running the local network who's charges are passed through the energy supply companies (to the consumers) they have little contact. The TNO on the other hand has an association through the connection of generation to the network, which is beneficial to both parties.

Relationship 'E' (Government Organisations – Regulatory Based Stakeholders)

It could be argued that because of monopolies of the networks, the regulatory based stakeholders, are currently dominated by Government Organisations, with pricing controls set out in advance attempting to develop greater efficiency within their sectors. However, with a reversal in power it is possible that the regulatory based stakeholders would pursue a more aggressive portfolio for greater profits to the detriment of the consumer and the energy companies. This is because of a duty to shareholders to glean maximum revenue (Kay, 2013).

The reality here is that the regulatory based stakeholders as monopoly companies will always need regulating. Their future may see the DNOs with a greater activity on the network, with a possibility of balancing both supply and demand. However, this will still be closely followed by Government stakeholders.

Final link Civil Society - Regulation Based Stakeholder

The electricity consumer has a wide choice of supply companies and the means to compare electricity unit prices through internet comparison sites; an underlying cost as part of their bill is a charge to the transmission and distribution operators. The cost of this is controlled by the network operators who work as regulated regional monopolies and could be considered as being hidden from customers (Cotton and Devine-Wright, 2009). Another connection civil society makes with the regulation-based companies (such as network operators) is when there is a connection problem. However, these limited connections between these actor groups provide little for discussion.

Governance patterns need to change in two ways in order to move to a decentralised electricity system. Firstly, the influence of civil society actors on the electricity system would need to be increased in terms of being involved with the balancing of supply and demand. The reason for this is to bring the householders, businesses and communities closer to becoming market-based stakeholders. This means that market stakeholders and consumers could become a single actor group. This is achieved by the consumers having a 'stake' in the generation side of the electricity system and demand side through the introduction of a billing system closely linked to the day to day market price.

The second requirement for change in the governance of the UK electricity system is a need for greater direction from Government. The relationship of the Government to the rest of the system actors and the main decision makers, mean that the UK Government may be perceived to have the greatest power and therefore be in the best position to drive change. This is not simply the case for moving to a decentralised electricity system; it is a requirement for moving to any low carbon electricity system whether it is decentralised or centralised. The transition requires strong and purposeful decision making from Government players.

6.4 Governance of a Transition

The future of electricity will require the move to a low carbon system. This could be achieved through a centralised or a decentralised approach. There are a number of potential issues which might affect the move from a centralised to decentralised electricity system. For example, the goals of each institution may not be aligned; Ofgem's role in the past has been to protect the interest of consumers by promoting effective competition between those engaged in the generation, transmission and distribution of gas and electricity (Pollit, 2008). However, this may not have been consistent with the Government's energy and environmental goals at the time (Parag and Darby, 2009). While the Government had goals of promoting renewable generation, Ofgem's role of promoting competition meant that the cheapest forms of generation would benefit, making it difficult for nascent renewable technology to be introduced (Parag and Darby, 2009). The role of Ofgem since then has been amended to incorporate the consumers interests which include a reduction of greenhouse gasses (Ofgem, 2012k). More recently the 2012 Energy Bill uses the introduction of a Strategy and Policy Statement (SPS) to improve regulatory certainty by ensuring that Government and Ofgem are aligned at a strategic level.

Another example is the extent to which individuals are included in the decision making process. The majority of involvement for consumers in the electricity system is limited to the selection of which supplier to use, leaving their views on the operation of the electricity system unheard. The difficulty here is the nature of a centralised system means that the energy companies who are already established would be able to promote the centralised model over decentralisation (Unruh, 2000; van der Vleuten and Raven, 2006).

This indicates that the governance of the electricity system is not always clear, stakeholder groups can often have different ideas on the future of the electricity system. Therefore, in order to move from a centralised to decentralised electricity system within a dictated timeframe then positive action or reinforcement from one or more stakeholders who hold the power to make the change will need to be made. This can be achieved by Government establishing strong policies and mechanisms which promote small-scale renewable generation; through consumers speaking out for how and where they want their energy to be generated; or by investors proactively identifying decentralised generation as their investment strategies.

If a decentralised electricity system is established then the governance of the electricity system will alter dramatically. The main impact will be the large numbers of smaller owners, bringing a greater interaction between the consumers and the energy system.

6.5 Summary

This chapter has discussed the transition theory of moving from one system to another. It has focussed on the electricity system and specifically on the move from a centralised system to one dominated by decentralised generation and ownership. The UK electricity system can be considered to be locked-in to a system of centralised technology and operation. This lock in may be linked to the investments sunk into centralised technologies, to the organisational and market structures together with user practices and lifestyles. This makes it difficult for new approaches such as decentralisation to get established. This could also be considered to be a locking out of decentralisation and therefore a transition is needed in order to 'break' this lock if a decentralised electricity system is to be achieved.

The previous chapter discussed the concept of decentralisation as not being just a technical issue, but also includes the introduction of a large number of smaller stakeholders. Therefore, any theory discussed will need to incorporate the actors and stakeholders as a major function of the analysis. This thesis looked at many different theories from transition management, niche management and technical innovation. However, the theory best suited to the situation posed by this thesis is deemed to be the multi-layer perspective. This incorporates a holistic view of a transition identifying the 'environment' or the overarching drivers for a change, the regime aspects such as policy, culture, society , markets and technology, and it incorporates the influence of a niche development in the transition itself.

Transition theory provides an overview of a possible move from a centralised to decentralised electricity system. From this it is clear that the governance pathways of the electricity system will play an important role in helping to break the lock-in of centralisation. Governance is defined in this thesis as; the organisation of stakeholders within the electricity system as well as the rules and incentives which enable the system to achieve the desired outcome.

The classical governance theories suggest a hierarchical structure, where government is placed at the top. This is from the government being the decision makers and potentially holding the greatest power, where power has the ability and want to create change. However, more modern theories suggest a network approach where formal or informal networks of actors who have the same vested interests work together for a common goal. In terms of policy these networks of actors are looking for a particular policy outcome. The multi-level perspective provides an analysis which does not reject the hierarchical structure with government at the top, it actually looks at actors or networks of actors in different levels of power or responsibility. Thereby identifying the importance of understanding the power relationship between actors and the responsibility of the actors in the energy security.

From this a consideration of governance needs to identify the interaction of the actors not only with each other but with the rules, regulations and incentives of the electricity system. This implies that the definition includes the organisation of stakeholders within the electricity system as well as the rules and incentives which enable the system to achieve the desired outcome.

In the past, discussions around the electricity system transitions have tended to focus on the quantitative issues such as price, capacity and technology, which can be measured and projected for the purpose of developing future strategies (Connor et al., 2007; Goldthau and Witte, 2010). However, many of the dimensions that can impact on the electricity system cannot be measured. These can range from the social and behavioural interactions of individuals and institutions, to the rules set out in the energy system, making the analysis of energy security far more complex (Sovacool and Mukherjee 2011). In addition to this the responsibility, power and direction of each actor can influence future changes. Therefore, by focusing on the institutions and the rules that form them, a more holistic perspective of energy security can be achieved.

Following the move away from the 'command and control' model to a market-based electricity system means that policy making for the electricity system is often organised through market mechanisms and the implementation of regulatory frameworks (Moran, 2003; Mitchell, 2008; Bolton and Foxon, 2010 Goldthau and Sovacool, 2012). Successful markets need governments to create and defend conditions (Scrase, 2009). The UK Government can enact overarching policies which affect the market and market players. However, with a market-based electricity system the Government no longer decides on the allocation of capital, technology or power.

This thesis has shown the background to the electricity system, identified the main policy goals and targets for the electricity system to achieve and discussed the evolution of the electricity system since the 1990s. It has provided discussions on the concepts of energy security, decentralised electricity, transitions and governance. Each of these chapters has been leading to the overall purpose of the thesis, which is to look at the governance implications for energy security of moving the UK electricity system from a centralised to decentralised operation. The next chapter will discuss the aims of the thesis identifying the objectives of the thesis and the methodology behind achieving these objectives.

7 Aims and Methodology

This chapter sets out the aims and methodological approaches used for this research, including the primary data collection, using a variety of qualitative approaches: the main research strategy used semi-structured interviews from purposively selected participants, backed up by data from UK Government consultation responses and a review of grey literature such as conference reports and non-indexed journals as a secondary source of data. The data collected from these sources was analysed using a 'qualitative content analysis' framework.

The focus of this research is to look at the implications of energy security for governance of decentralised electricity, concentrating specifically on the UK electricity system. The nature of such a topic of discussion means that the networks of actors and stakeholders involved stretch from the household and local level, up to Government and transnational companies and institutions. The multifaceted dimensions of energy security and the multi-level nature of transitioning to a decentralised electricity system means that there will need to be a diverse selection of research participants. Any focus to a specific and localised area would not provide the range of understanding required to answer the research aims. Therefore, the research participants are taken from a range of actor groups (see section 6.3).

This chapter begins by setting out the research aims. It then identifies and discusses the primary research methodology, including how the participants were identified and the potential pitfalls surrounding this. It will also set out the process used to analyse the primary data. The analysis of this data will then be discussed in relation to the theoretical governance processes discussed in chapter 6 in order to establish any correlation between governance theories and the current governance of energy security. Finally it will examine the changes a decentralised electricity system may bring to the governance of energy security.

7.1 Research Aims

This thesis will add to the understanding behind the energy security of a decentralised electricity system, exploring the governance implications for the UK electricity system. It will answer:

- **How will a decentralised electricity system change the governance of energy security?**
- **Who is responsible for energy security (not just supply)?**

7.2 Methodology

The primary research of this thesis will be obtained through the qualitative data collection from a series of semi-structured interviews and consultation documents based around the topic area. This section explains the processes of the data collection involved, the reasons behind such processes and how the data has been analysed.

The primary research of this thesis contains 31 in-depth interviews with key actors within the electricity sector. The majority of the interviews lasted between 1 and 1½ hours. The interviews were designed in a semi structured format meaning the researcher had the ability to ask additional questions in order to follow up salient responses (Legard et al 2003; Denscombe, 2009). As far as possible the interview questions were identical, although the different roles and responsibilities of the participants inevitably meant that there was a degree to tailoring each interview to reflect different areas of expertise. A sample of the questions used within this research can be found in Annex A.

7.2.1 Why use interviews?

Interviewing could be considered as the most frequently used method of collecting qualitative data (Seale, 2004; Arksy and Nilson, 2008). The use of interviews in qualitative research provides the ability for the researcher to gain a greater depth of understanding of a participant's perspective when compared to more structured tools such as questionnaires. This is achieved by the one to one interview, allowing the researcher to further question specific aspects when in subjective topic areas such as the electricity system (Bryman, 2008). The purpose of interviews for this thesis is to establish the participants' perceptions of the governance of energy security and how a decentralised electricity system may impact on this. The views and understandings of the participants will come from their level of experience in a specific area whether this is the market, R&D or investment. With a wide range of differing participant understandings and knowledge together with the multifaceted nature of energy security, the interview process will provide the best methodology for collecting the information.

While the interview process does provide a richly informed depth of information from the research participant, it can have some pitfalls. One such issue is that of 'interviewer bias', where the interviewer influences the responses by providing too much information of personal experiences or through leading and 'loaded' questions (Jones, 1985). Due to the complex nature of the research, with many facets and definitions requiring explanation, the information provided to the interviewees was carefully structured in an attempt to ensure no suggestion of bias.

Another issue to be aware of surrounds the structure of the interview itself. This includes the length of time given to each question, the order of questions and the level of interaction with the interviewee. If the structure is rigid and inflexible then relevant information may not be accessed. If the interview is unstructured then finding comparisons between research participants could be difficult to analyse and justify. Having said this, an interview can not be fully unstructured or predetermined (Jones, 1985). Therefore, this thesis will utilise the semi-structured format of conducting interviews to collect the data required whilst being able to provide an analysis of the final data.

The use of multiple actors provides a range of perceptions that help to clarify meaning and verify an observation or interpretation (Stake, 2005). The use of semi-structured interviews can help given the range of experience and knowledge of the interviewees. This breadth of expertise is necessary in order to cover all actor groups within the electricity system and means that each participant would be able to provide varying degrees of depth and information. For example, many of the local Government actors may have a high understanding of issues around skills and planning, however, with little interaction with the electricity markets the level of knowledge in this area may not be as apparent.

7.2.2 Recording and transcription of the Interview

Qualitative research data in this thesis is primarily provided by the information delivered from the research participant. This includes what they say and the way in which it is said (Bryman and Teevan, 2005). Therefore, a combination of a Dictaphone for transcribing the information at a later date, as well as written notes of the significant additional points during the interview was used.

The transcription of the interview recordings was done verbatim, meaning that if any feature of the research changes, the full interview was available and a secondary analysis could be made. The interviews were transcribed soon after the interview had taken place in order to establish any additional information which would be required.

7.2.3 Sampling technique

The power and relationships of the key-governing actors within a centralised electricity system are likely to change in a decentralised electricity system. This change can include who the key actors are and their relationships within their network. Without a prior understanding of how the research participants would discuss the topic and how the power and relationships operate within their networks, it is important to apply a reflexive approach to the research participants and the structure of the interviews (Denzin, 2001).

Any predetermination of research participants without prior understanding of their views on the dimensions associated with the research, could result in 'steering' and causing personal bias. Therefore, a snowball method was identified as a suitable approach to deal with the intricate relationships and the complexity associated with energy security (Kvale & Brinkmann, 2009). Snowballing is the method of using the research participants knowledge of relevant potential interviewees to help find subsequent research participants through. Snowballing was developed as a solution to overcome data solving problems such as the studying of hidden populations where finding relevant participants may be difficult (Atkinson & Flint, 2001). Such hidden populations occur when adequate lists and sampling frames such as conference and meeting places are not readily available (Faugier & Sargent, 1997). Although, within the electricity system such sampling frames do occur, for instance: government consultation documents, conferences and network meetings. However, engaging in conversation and finding the right participants for the research is easier to achieve when organised through one of their peers.

In order to examine the relationship between the stakeholders involved in a particular policy, a network analysis can be used. Policy network analysis takes the understanding that policies are not simply run by government agencies, but include the relationships between government-based stakeholders, market-based stakeholders and civil society. It also includes factors such as economics and market changes (Parag, 2006). Although the theoretical development of policy network analysis concentrates on establishing the different networks at play (Smith, 2000), its significant attribute is the ability for explaining policy outcomes.

Marsh and Rhodes (1992) identify two types of policy network; 'policy communities' and 'issue networks'. The 'policy community' model interprets the network as a tightly integrated and single-minded policy network (Marsh & Rhodes, 1992; Peterson, 2003). This is a network of 'closed' clusters of actors usually involving Government agency and a close group of stakeholders who have a shared ideology about a policy sector. On the other end of the policy network scale are the issue networks which use many stakeholders groups or communities with conflicting philosophies on the solution to a particular policy area. The fluctuating nature of the policy area causes the 'membership' of these competing groups to change and interaction to be irregular (Peterson, 2003). These policies network are identified through three main categories: firstly, the stability of the networks members, secondly, the interaction with outside actors with different objectives, thirdly, the strength of its resources, do the members rely heavily on each other or are they independent (Peterson, 2003).

The current electricity system regarding energy security clearly falls within the policy community category. The single goal of the community, is the security of the electricity system. The actors within the electricity system can also be considered 'closed'. The electricity system actors can be defined by their 'stake' or power in the electricity can be constrained by the boundaries of an electricity system actor, which include the policies, incentives and mechanisms defined by Government.

The use of network analysis provides the ability to address a wide range of questions. However, the interpretation of the data is subjective, the support or objection to a particular solution cannot be measured. There is no uniform definition of stakeholders or policy networks, therefore establishing links between stakeholders will be difficult to achieve (Runhaar et al., 2005).

The system this study will look at the four groups identified above government-based stakeholders, market-based stakeholders and civil society with the inclusion of the regulatory based stakeholders.

In order to analyse the different policy networks the research will have to:

- Conduct an audit of relevant agencies
- Draw a strategic map of key relationships
- Identify which of their resources will help them to influence these other agencies

Any predetermination of research participants without prior understanding of their views on the dimensions associated with the research, could result in 'steering' and causing personal bias.

7.2.3.1 Problems with sampling techniques

Issues with determining research participants can occur with the hidden populations of 'policy communities'. Such hidden populations occur when adequate lists and sampling frames such as conference and meeting places are not readily available (Faugier & Sargent, 1997). Although, within the electricity system such sampling frames do occur, for instance: Government consultation documents, conferences and network meetings. However, engaging in conversation and finding the right participants for the research is easier to achieve when organised through one of their peers.

Within this thesis the pursuit of establishing each actor group or network's position on the research topic will not be achieved easily. One reason for this can be that each individual in a particular organisation or institution may have separate views which do not coincide with each other. This would mean that the selection of research participants could provide differing outcomes.

This idea is particularly relevant when looking at consumers. Although the consumer group currently could be considered as not having any significant role to play in the security of the electricity system, with a more active demand network (see section 3.2.1) and greater levels of consumer engagement, the future role of the consumer is likely to be very different (Ipsos Mori, 2013; Gangale et al., 2013)

In addition to this the consumer group consists of a wide variety of sub-actor groups from individual consumers to the larger businesses who are likely to have different ideologies on the electricity system.

In order to achieve an idea of the varied opinions and perspectives of the consumer group a disproportionate number of participants would have been needed in comparison to the other actor groups. The complexity of the discussion would also have meant that the questions may need additional explanation altering the interview structure between participants and making the cross referencing of the data more difficult. In order to combat this problem the use of organisations which attempt to voice the concerns of the individual householder within the energy system, such as Consumer Focus[25] is used.

Another problem is the engagement by respondents as informal research assistants. Within the field of research there are a limited number of applicable persons to interview. To solve this problem the researcher invited a number of participants with the understanding that many would not be able to participate, leaving a small number of replies.

In addition to this the problem associated with the control and monitoring of the chain or network. The issue here is that the type of network would need to be analysed and a reflexive approach used to ensure bias is not established and proportionate number and level of experience is found from each of the actor groups. However, any attempt to control the research direction would itself provide bias. Therefore the selection process had to be scrutinised closely ensuring a wide diversity of participants from all actor groups.

7.2.4 Contact of Research Participants

After the selection of research participants potential interviewees were contacted. Although the sampling ratios of the research participants is important to the analysis of the data and was carefully organised, not every participant contacted is likely to respond. In some cases it is difficult to establish contact and achieve any response at all. There are ways in which a higher response rate can be achieved, such as face to face meeting at conferences and seminars rather than using a 'blind' email approach where the lack of personal interaction results in a lot of negative

25 Since the completion of the primary data collection Consumer Focus has changed to Consumer Futures responses. However, the face to face approach often meant that the interview would take place at short notice. Another option is to follow up any request with a telephone call. However, this also means that the interview may take place at short notice and over the telephone requiring additional technology to record. It also means the researcher looses the interactivity with the research participant making it more difficult to note mannerisms and the willingness of a participant to provide additional information (Denzin, 2001).

7.2.5 Actor Groups

For the purpose of this research, the research participants will be categorised into four groups. With a large number of interviewees comparing the responses to a particular theme would prove complex. Therefore, the categorisation of research participants provides a way of discussing the reactions and responses between the four groups. The groups used are as identified in section 6.3.2 and include: Government, Regulatory, Market and Civil Society (see Figure 7-1 and Table 7-1). Although the actors have been categorised, there is an argument to say that many of the participants could be placed in more than one category, which would ultimately make the analysis of this thesis overly complex. The issue with this may be that different participants from within a specific category are likely to have different views. Therefore, a single reference to a participant does not provide a response from the actor group as a whole, or that another participant in the same category has a similar ideology.

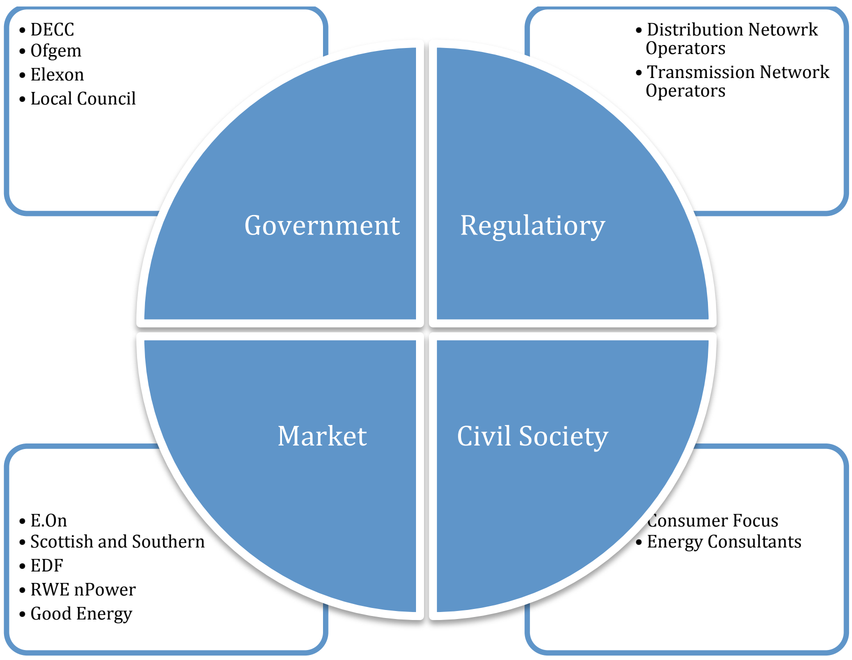

Figure 7-1 Diagram of Actor groups including additional detail on the companies.

Table 7-1 Interviewee list

Interviewee No.	***Actor Company/Department***	***Actor group***
Interviewee 1	*DECC*	*Government*
Interviewee 2	*Cornwall Planning*	*Government*
Interviewee 3	*E.ON*	*Market*
Interviewee 4	*Chatham House*	*Civil Society*
Interviewee 5	*DECC*	*Government*
Interviewee 6	*RWE nPower*	*Market*
Interviewee 7	*Micropower Council*	*Market*
Interviewee 8	*European Environment Agency*	*Government*
Interviewee 9	*National Energy Action*	*Civil Society*
Interviewee 10	*Association of Electricity Producers*	*Market*
Interviewee 11	*CE Electric UK*	*Regulatory*
Interviewee 12	*Cornwall Energy*	*Civil Society*
Interviewee 13	*ELEXON*	*Government*
Interviewee 14	*ELEXON*	*Government*
Interviewee 15	*Good Energy*	*Market*
Interviewee 16	*Good Energy*	*Market*
Interviewee 17	*National Grid*	*Regulation*
Interviewee 18	*Scottish and Southern*	*Market*
Interviewee 19	*National Grid*	*Regulation*
Interviewee 20	*Cornwall Energy*	*Civil Society*
Interviewee 21	*Ofgem*	*Government*
Interviewee 22	*Ofgem*	*Government*
Interviewee 23	*Western Distribution*	*Regulation*
Interviewee 24	*Cornwall Council*	*Government*
Interviewee 25	*Progressive Energy*	*Market*
Interviewee 26	*EDF*	*Market*
Interviewee 27	*Consumer Focus*	*Civil Society*
Interviewee 28	*Centre For Sustainable Energy*	*Civil Society*
Interviewee 29	*E3G*	*Civil Society*
Interviewee 30	*Energy Technical And Renewable*	*Civil Society*
Interviewee 31	*Ernst and Young*	*Civil Society*

7.2.6 Ethics and Consent

The ethical considerations for this research will follow the University of Exeter guidelines. The purpose and outline of the study sent to each person prior to each interview ensuring an understanding of the work involved. The recordings and transcriptions stored as per university guidance (University of Exeter, 2011). There is a list of the interviewees in Table 7-1, however, they were assured that their comments would be non attributable within the research. The reason for anonymity is that it lets the interviewee speak freely and frankly about the research topic. This provides a more complete discussion where the interviewees are less likely to restrict the depth of information provided as not to contradict the company position.

7.2.7 Pilot Study

Before the primary research was carried out a pilot study was undertaken with an interviewee who understood the purpose of the pilot and had knowledge of the electricity industry and therefore could provide feed back. The pilot study was to ensure questions were equal in depth to provide a similar length and did not lead the respondent in any particular direction. The result of the pilot study meant that additional clarity was required in the definition of energy security and decentralised electricity generation for the interviewee.

7.2.1 Design of Questions

The interview strategy had two primary functions. Firstly, to establish the stakeholders perceptions of the move to a decentralised electricity system, and the impacts of this move on the governance of energy security. This is achieved by investigating the various aspects of energy security and decentralisation. These aspects will need to take into account the concerns around investment, the market arrangements, knowledge and skills, the changes to distribution network operators and the changes to consumers.

The interview was structured to cover more complex questions as it went on. This means that the interviewee is given the chance to get comfortable with the type of questions being asked (which may or may not come up in their daily routine).

Further to this, the level of understanding around the electricity system would differ between stakeholders. An example of this is the distribution network operators would likely understand the potential changes to the distribution network however, may not have the same level of knowledge of the way in which the markets operate. Therefore, prior to the commencement of the interview the research participants were provided with a note on the nature of the research being undertaken, along with a definition for the purpose of the thesis of energy security and decentralised electricity. Therefore, the beginning of the interview was given to answering any questions over the different definition to ensure the participants each had the same concepts.

The concepts of both energy security and decentralisation of electricity are multi faceted and can have different meanings between stakeholders (these concepts are defined in chapters 4 and 5 respectively).

During the primary data collection of this thesis an interesting theme developed; 'responsibility', which discussed the idea of who is responsible for ensuring energy security and would this change in a system dominated by decentralised electricity generation. From this it was decided that this would make an interesting point in the research and was therefore added to the list of questions which can be seen in appendix A.

7.3 Analysis

The previous section has outlined the methodology behind undertaking interviews. This section will look at the analysis of the data collected. This thesis has defined and developed the main aspects to be discussed in this research: energy security, decentralisation of electricity and the governance of energy policy. The research consists of 31, in-depth interviews with key stakeholders of the electricity system from the government (GBS), regulatory (RBS), market (MBS) and civil society based actor groups (CSBS). In addition to this, the research used a secondary analysis of consultation responses and Government publications.

Due to the data collection methodologies there was a large volume of material to process. Therefore an initial stage was to read through all materials in order to gain an overview of the data and understand the discussions involved (Ritchie et al. 2003). After this it was necessary to synthesise and condense the data to ensure the data was based around the research question posed for this thesis.

The process of analysis often takes a step approach to the interview transcription (Strauss & Corbin, 1998; Denscombe, 2009). The steps are generally made up of the preparation, familiarisation, interpretation, verification and representation. For the purpose of this research the transcripts will be analysed using a 'qualitative content analysis'(Seale, 2004).

A content analysis examines the text and codes it into pre-determined categories in a systematic manner in order to analyse the large amount of text which will be produced. The coding will extract the various separate ideas, which relate to the aims set out in the research. This provides a large number of topics for discussion, which are then categorised into a smaller number of overarching themes, which provide the separate headings for discussion (see Table 7-2). It is important to note that the five stages above do not need to be arranged in any specific order. They do, however, need to be thought about as the analysis progresses. This is because as the coding of the transcripts occurs, what is an important aspect at the beginning may completely change by the end. This is discussed as 'analytical hierarchy' in (Spencer et al 2003).

Table 7-2 Coding data (Corbin and Strauss, 1998)

- Categories – Higher-level concepts which analysts groups lower level concepts according to shared properties. Categories are sometimes referred to as theses. They represent relevant phenomena and enable the analyst to reduce and combine data.
- Coding – Extracting concept from raw data and developing them in terms of their properties and dimensions
- Concepts – Words that stand out for ideas contained in data. Concepts are interpretations, the products of analysis.
- Dimensions – Variations within properties that give specificity and range to concepts
- Properties – characteristics that define and describe concept

The advantage of using a qualitative content analysis is the level of repeatability in the process, meaning similar results are possible if the work were to be re-analysed depending on how much researcher interpretation is used. For instance, one of the important aspects of coding the transcripts is the 'weighting' given to a particular statement. Weighting is an interpretive aspect which will be done by the analyst, therefore, a level of subjectivity is involved in the work.

Another advantage is its ability to deal with complex and subjective topics. A more quantitative approach would be to use computer software like NVIVO to retrieve segments of text. The subjective nature of the works and the terminology used in the electricity sector would provide too many variables. For example, the term decentralisation refers to the technology being directed at the distribution network and the ownership associated with the householder and smaller energy companies, therefore the terminology used for this may include 'small–scale', 'distributed', 'embedded' and often 'renewable' each of which does not denote an aspect of ownership.

Disadvantages of qualitative content analysis include the level of coder interpretation. Analysing any document will require a level of interpretation as discussed earlier. This level can be questionable as to whether it will generate bias in the results.

Once the fieldwork was organised and categorised into separate themes, the relevant material was then processed again in order to extract the overarching topics for discussion. These topics are analysed for any classifications, patterns or connections between the stakeholder groups as identified in section 7.2.5. The themes and topics which emerge have been used to challenge or confirm the literature and develop research aims to further the understanding of decentralised electricity generation's implications for the governance of energy security.

The use of this methodology provides a rigorous and reliable format for the research to be undertaken. This also requires the researcher to fully partake in this rigorous methodology understanding and adapting to any changes which may occur. These changes can be to the subject nature, which for energy policy is constantly changing, with new data, policies and players. But also to develop further any relevant or interesting topics which may arise.

8 Moving to a decentralised electricity system

8.1 Introduction

As outlined in earlier chapters, the UK electricity system faces a number of "unprecedented challenges" (DECC 2011b), which need to be addressed in the coming decades. One of these is the decarbonisation of electricity generation, driven by concerns over climate change. However, this must be achieved in the context of other interlinked Government goals of maintaining energy security and ensuring that energy remains affordable.

These challenges mean that the future of the electricity system is likely to be very different than it is today. The move to a low carbon electricity system will require a major change to the current operation and governance processes (Karger and Hennings, 2009; Delta 2010; Watson and Wright, 2010; Finney et al 2012). The governing of a decentralised electricity system would likely require different processes for regulation, markets, incentives and will include different stakeholders than the present system. Therefore, understanding of the technical aspects for a move to a low carbon system would not provide the whole picture, and a broader view of the drivers of the electricity generation should be adopted. This thesis examines some of the issues raised by the research participants in moving to a decentralised electricity system.

This chapter will look at the research participants' understanding of a highly decentralised electricity system's impact on the future electricity system and the issues surrounding it, such as a requirement for supporting transition technologies like natural gas electricity generation.

This chapter also looks at the security concerns associated with changing from one system to another, identifying skills and network adjustment as the main impact areas.

Although this thesis is not going to try to add to the discussions of the barriers to decentralised electricity generation, an understanding of what may happen in terms of security is worthwhile. The shift to a low carbon decentralised electricity system implies changes to the way the system is operated and how it is governed because of the higher level of localised and intermittent generation and an increase in the number of stakeholders active in the electricity system. Developing an understanding of the impacts of moving to a decentralised electricity system and how any issues can be dealt with is important.

In February 2002 Donald Rumsfeld famously made a statement to the press as United States Secretary of Defence:

> *"[T]here are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns – there are things we do not know we don't know" (Rumsfeld, 2002)*

The idea of understanding what will and what can happen in the UK electricity system is one of knowing all the unknowns (which is effectively impossible). It is important to understand the issues or risks to the electricity system, such as, domestic activism or terrorism, reliability of demand patterns, investment in infrastructure, technological failure and resource availability (see section 4.2.3)

8.1.1 What don't we know?

The interviews provided an idea of the understanding held by of some of the actor groups regarding the move to a low carbon future. A market based stakeholder identified this with reference to establishing secure small-scale renewable generation on the electricity system.

> *"So I think we've got to a point now knowing broadly speaking what we don't know. Now the industry is committed to learning all the things that they need to know." Interviewee 6 MBS*

It must be noted that the market-based stakeholder identified in the quote above is from one of the 'Big 6' energy companies (see section 2.10.1) This is relevant because the discussion of 'industry' is in the context of the current, centralised generation model. While it is significant that industry is committed to learning what they need to know, it is also worth being aware that this may be shaped by what the large centralised company's best interests are.

A decentralised electricity system approach could require understanding additional implications for the system as a whole, such as the interactions of different types of investor. A decentralised electricity system would introduce smaller investors who would be unlikely to have access to the same resources of information and knowledge as a larger centralised investor.

A counter argument to this was given by interviewee 11 a regulatory based stakeholder who identified that any changes to the current electricity system could bring unexpected outcomes and therefore, security concerns.

> *"I'm an engineer so we are always on our guard when somebody changes the fundamental specifications; it almost always brings something you didn't expect. Intuitively it must do. Right off the bat I can't think of what they are, therefore I'm prepared to say that they are probably down there in the 2nd or 3rd order." Interviewee 11 - RBS.*

This identifies that there may be some disagreement about the technical implications of more decentralised generation being connected to distribution networks. However, the regulatory based stakeholder here downplayed their significance meaning they could easily be remedied. One reason for this could be that the regulatory based stakeholder would be more focussed on the ability of the networks to receive decentralised electricity generation than on the generation technology itself.

Both of the examples above identify a technical based discussion of the electricity system and energy security. This is an indication of the way in which many of the energy system actors view the issues around energy security. With a broader approach to the future of the electricity system and an understanding of governance processes which can dictate the technical issues, a more universal approach to securing the future of the electricity system can evolve. This is shown in the definition of energy security provided by this thesis (see section 4.2)

There is an inherent difference between understanding the technical issues of an electricity system and understanding the governance implications. It is far easier to quantify technical issues however, governance implications can have multiple influences which, being difficult to predict makes the changes of a single governance aspect, whether it is a change policy or to the stakeholder very difficult to accurately predict.

8.2 Timescales of change

The electricity system is constantly changing and evolving through internal and external dimensions such as the economy's impact on the end price of electricity and the environmental impacts such as climate change (DECC, 2011a). As a result the electricity system needs to be dynamic and able to adapt to these changes as discussed in section 4.2. Therefore, fixing timescales are important for the development of the future of the electricity system. The factors affecting timescales can include: sourcing increased investment, the build times for networks and generation capacity.

The impact of policy can contribute to the time period over which a system change can occur, delaying or speeding up system change. From an investment point of view policies can provide a positive incentive for investors to develop new generation or alternatively it can be vague, leaving the future open to other options whereby investors may foresee their assets undermined this is discussed in further detail in chapter 9. Therefore, the lead-time it takes to build a generation plant and investment support implemented can have a huge impact on the ability for a system to adapt quickly.

8.2.1.1 Speed / cost / security triangle

The speed at which change takes place can have implications for the cost of the transition and for the implied security. This concern is noted by the Association of Electricity Producers (AEP) in the quote below, it refers specifically to the changes to the market through the EMR:

> *There should be an assessment of whether a speedy and radical implementation delivers the best results, compared with an option which delivers and number of quick wins followed by slower, more evolutionary, change (AEP, 2010).*

When changing to a supposedly 'improved' system (whether this is for improved security or environmental improvements) then instinctively a rapid change would be beneficial. However, interviewee 3 identified that a rapid change could also cause problems, such as, higher immediate costs are incurred from reduced technological development. In addition to this, new operational approaches need testing without which unforeseen issues could arise. This provides a time – cost – security relationship which is not straightforward. For example, solving an issue such as climate change over an extended period of time may not be the best approach as the damage may already have been done. This means the longer the remediations are left the costlier they may become.

8.2.2 Can enough low carbon generation be built to meet future capacity levels?

There are further implications for security with a move to a low carbon future; one of them is ensuring enough low carbon generation is developed to meet capacity levels. Concern for this was identified by Scottish and Southern Energy in 2011:

> *"Unabated coal is not an option because of its environmental impacts; CCS is not yet proven at scale; nuclear will take too long to build; and renewables can not provide firm capacity at the scale needed. Therefore the only technology which can provide firm capacity at scale, and be built in the timescales required, is gas."(SSE, 2011b)*

8.2.2.1 Is there such a thing as an energy gap

A concern surrounding the building of network generation is from the possibilities of an 'energy gap'. This is discussed in section 2.5.2 which identifies the closure of certain power stations, either from the end of their lifetime or through EU policies (see section, 2.5.1). However, interviewee 31 identified an additional aspect which is the future reduction in gas resources.

> *Government and policy makers need to be telling people that in 15 years there might not be gas in certain parts of the country and need to be shifting to electric heating in the home. (Interviewee 31 – CSBS)*

This civil society based stakeholder discussed the idea of switching to electrical heating as a requirement for future of energy security. What interviewee does not explain is that in reality as the level of natural gas resources decreases, the price of gas on the market increases. This is likely to occur until the cost reaches an unaffordable level, thereby forcing the user onto other forms of energy. However, a government based stakeholder, interviewee 8, countered this argument of an energy gap, stating it as a method of promoting future technology.

> *The politicians screaming about a supply gap or generation gap is bullshit really. But they use it to promote whatever pet project they have on. (Interviewee 8 – G.B.S.)*

The issue surrounding gas is that it will have a significant role in the future. As identified by SSE earlier gas is widely considered a 'transitional' fuel and therefore would likely have a strong role to play in the move toward a low carbon future. However, there is concern over the future use of gas as a support for low carbon technologies. Firstly, its ability to be implemented quickly:

> *The industry cannot react quickly to price signals in wholesale fuel markets, for example the timescale from initiation of a CCGT or Open Cycle Gas Turbine (OCGT) project to commissioning can be up to nine years. The UK needs a stable and predictable policy framework to attract the investment it needs within the necessary timescales (E.ON, 2011)*

There is a discussion over how quickly gas powered generation can be built. The figure for a lead-time for gas-powered reactor of nine years is long in comparison to a renewable portfolio. However, when compared to other centralised technologies such as nuclear generation it is relatively short. In addition to this, the nine year figure would likely include the planning phase while the construction times can be between 2-4 years (Watson, 2001; Carlisle and Webber, 2013).

Energy UK identified an additional issue for CCGT in the role of gas in the electricity market consultation. This was that without Carbon Capture and Storage (CCS) the use of gas in the future could only be limited. Therefore, in order for such technologies to be implemented, the UK Government would need to identify support for such projects also identified by Energy UK in the same consultation:

> *Government should aim to provide investors with clear signals and appropriate incentives to enable demonstration projects to come forward. (Energy UK, 2012)*

These identify the centralised plants such as coal with CCS and nuclear as having issues with build and development timescales which pin points a key negative aspect of centralised electricity generation: the length of time for each plant to be built. One example of this is the Olkiluoto Nuclear Power Plant in Finland. The third unit of this generating plant was contracted in 2000, construction started in 2005 and is as yet not completed (Rossi, 2013).

In contrast, some interviewees were relatively relaxed about the implications of a shift to a more decentralised system. Maintaining a short-term, gas based approach implies new capacity can be built in around 7 years, timescales for enabling a more decentralised system may not be much longer, and one market-based interviewee was clear that he did not see this as a security risk:

> *"With the length of time to move from a centralised system to a decentralised would be 10-20 years and therefore the changes required are not an issue for security" (Interviewee 6 - MBS)*

The "issue for security" discussed here is; if Government made a clear statement about its intentions for the future of the electricity system, then the transition period would mean reduced investment in maintaining the current system. In addition to this if the market structures and governance processes were established for decentralised generation then long lead times could have implications for security, as identified by interviewee 3 (a market-based stakeholder).

> *"If there's a gently-gently-steady-as-it-goes sort of revolution then it might not be an issue, but when we try and push things through very quickly then yes I do suspect there will be a significant problem finding the relevant qualified people."*
> *(Interviewee 3 – MBS)*

What is interesting here is that both the market-based stakeholders quoted above, represent large energy companies and indicate the requirement for long lead times to move from a centralised to decentralised system. However, for the current centralised electricity system to stay centralised and move to a low carbon operation, it is likely that a large amount of nuclear generation will be required. The issue with this is the lead times in order to build a single nuclear power plant are long in comparison (especially when discussing the Olkiluoto Nuclear Power Plant in Finland as identified earlier) to other forms of generation such as gas or renewables (Schlissel and Biewald, 2008). In addition to this the UK has not built a nuclear power station since 1995 (Sizewell B), even though the technology and skills can be imported there may be additional unforeseeable issues. In the same way there are likely to be issues with integrating a large amount of decentralised electricity in the current system.

8.2.2.1 What impact could these longer timescales have on the energy system as a whole

The concept of the timescales is important for meeting the Government goals and target. However, it is also important for establishing the governance processes. As discussed in section 6.3, governance is a cyclical concept where the rules and incentives set by the actors and stakeholders also develop and change the actors and stakeholders. Therefore this cyclical process needs time to occur for the governance to stabilise. If the process is rushed the appropriate rules and incentives may be in place without the right stakeholders to carry them out, thereby possibly causing issues for security.

There are two main aspects in terms of timescales: firstly the time restrictions on moving to a low carbon system. This is set by policies and the need for it to occur quickly (in terms of mitigation, the quicker the better). Secondly the speed at which an electricity system can move from centralised to decentralised. The research has shown that the general consensus among each actor group that the as long as the transition is not sudden change then there is no obstacle that cannot be overcome. This next section will look at what issues a decentralised electricity system may encounter.

8.3 Skills

A key aspect of discussion in the move to a decentralised electricity system is need for skilled personnel. A lack of such personnel is a potential security issue for any low carbon system. The skills required in order to run an electricity system include the ability to install and maintain generating plant and networks, as well as the ability to plan, finance and operate the plant installed. Without the right skills and knowledge base the security of any electricity system may be compromised through operational or technological failures. These include the market mechanisms being able to incentivise enough capacity at times of peak or simply not being able to maintain the generation plants to keep them running efficiently.

8.3.1 What are the different skills and knowledge requirements for the move to a decentralised electricity system

The requirement for additional skills in a decentralised electricity system are often identified in the literature as a necessary part of any transition, but only as a point to say this is an unknown factor (Foxon et al., 2005; HM Government, 2009; DECC, 2011a). However, it is likely that the change in skills will include the operation and maintenance of the smaller scale generation plants and the operation of more active distribution networks (DECC, 2010b). Changing generation technologies and the organisational systems in which they run means a change in the required skills. This means there is a requirement for knowing what skills are required and the length of time it takes to establish the knowledge and understanding, will be essential to access their impact on security. This can be achieved by setting a clear understanding of the future electricity system and utilising examples from other countries such as, Denmark, who already have a significant level of low carbon generation (Lund and Mathiesen, 2009). Since the introduction of the feed in tariffs the finance, planning and installation of small-scale decentralised electricity generation has started to become more established. However, it is still unclear whether the maintenance of these technologies, including the development of supply chains have been established (Willis & Scott, 2000). Once again the literature discusses skills development as a requirement for change and that new strategies and policies for the on going promotion of decentralised generation will need new skills although it is difficult to be specific as to what those skills are (Chester, 2010).

Discussion of skills in Government documents are prolific yet not definitive (HM Government, 2009; DECC, 2010d; 2011b; 2011d). Specifically, in the transition to low carbon energy system, the concepts of skills are discussed throughout but without any indication of where there may be a lack of skills. In the research literature there is very little discussion, especially when looking at the issues around security. It is often discussed as an additional point that there is a requirement for skills development within this area without identifying any specific areas for attention.

In 2009, Malcolm Wicks was appointed by the Prime Minister as his Special Representative on International Energy and was tasked with providing a review of the implications of international markets to energy security. In this review the concept of skills shortages was highlighted for the oil and gas industry. It stressed the risk to investment in the industry from shortages of highly qualified specialised workers, showing how the long lead times for training people could cause problems for future capacity. In order for generation plants to operate there must be skilled individuals to fill the gap. Higher wages would be introduced having a direct impact on the production costs which feed down to the consumer (Wicks, 2009). However, the level of impact this may have is not yet understood.

In 2010 the Government set out a consultation "Meeting the Low Carbon Skills Challenge" in order to understand the key skills-related priorities and challenges to be met. The consultation looks at how to:

- Enable British workers and businesses to take advantage of the opportunities in the sectors key to reducing carbon emissions and
- Embed the necessary skills across all sectors to move the UK to a low carbon and resource efficient economy (DECC, 2010b)

This shows that the Government have identified a skilled labour force as an important factor in the future energy system and acknowledged that as the skills requirements for a centralised system would be different to that of a decentralised system. The majority of the skills needed for decentralised electricity could be found in the UK. The development of relatively small renewable generation plants can be achieved without importing engineers or operators. The construction of renewable technology is fairly well understood in this country. However, the skills required for a nuclear generation plant would not be so readily available and may require international help. Therefore, without strong direction on how the future energy system will look, an understanding of the skills required would prove difficult.

8.3.2 Skill levels and availability and geography

One thing that became clear in the course of the interviews was the difference in approach to skills at different scales of decentralised electricity. In the example of microgeneration deployed as a result of the Feed in Tariffs, there was a feeling across all actor groups and stakeholders, that the necessary skills could and would be covered by existing tradesmen expanding their portfolios:

> *"you see a lot of plumbers and electricians, small business men getting involved becoming accredited installers and it's a big boost for small businesses like them. Those guys aren't just in one or two parts of the country. They are spread everywhere. So you are talking about spreading the benefits of encouraging low carbon growth and encouraging low carbon investment in the economy." (Interviewee 15 – MBS)*

This increase in the level of local skills is likely to have a positive impact on the local economy, reducing the reliance on finding and importing higher level skills and knowledge into the UK which may be more costly (DECC 2011b).

However, a counter argument was provided by E.ON in the "The UK's Energy Supply: Security or Independence?" consultation. This opposing point of view by is in reference to the larger scale decentralised electricity installations, industry in particular has expressed concerns about the availability of sufficient skills:

> *"Investment in any infrastructure relies heavily on the wider supply chain providing both materials and skills. Security of supply is very sensitive to the availability of these" (E.ON, 2011; p.56)*

The issue of supply chains, in theory, could be relieved by diversity in technology and technology suppliers. The majority of skills for a decentralised electricity system could easily be found in the UK (DECC, 2011b). However, as discussed by interviewee 3 the remnants of a centralised system would also exist.

> *"Even a nuclear no vote could actually demand lots of nuclear skills to be brought into play." (Interviewee 3 – MBS)*

What interviewee 3 is discussing here is that the closure of a nuclear generation plant would require decommissioning which is considered a highly skilled job set. This means that the transition to a low carbon decentralised electricity system will require an increase in 'low level' skills at the same time as finding the 'higher level' skills required to close many of the larger power stations.

Interviewee 3 sees the development of skills dependant on the time scales which relates back to section 8.2 of this chapter

> *"If there's a gently-gently-steady-as-it-goes sort of revolution then it might not be an issue, but when we try and push things through very quickly then yes I do suspect there will be a significant problem finding the relevant qualified people." (Interviewee 3 – MBS)*

It is arguable that with sufficient education and training, the necessary skills for decentralised electricity generation would become available. However, this depends on the timescale on which the skills are required – if policy is driving a more decentralised system at a rate at which the education system is unable to match in terms of providing skilled personnel, then the lack of skills becomes a significant security bottleneck.

The main issue with this is the level of skills which are found in the UK. Interviewee 6 identified this.

> *"You would argue that we have a better skills base in this country to deal with renewables than we do with nuclear, because we have not done nuclear for ages other than keeping the existing ones running. But we are planning to build 6-7 new nuclear power stations. Renewables are in their own sense more simplistic so to take the micro generation level, the micro gen strategy came out yesterday, or the response to it. The general view was that there were plenty of skills out there, they are plumbers and electricians." (Interviewee 6 – MBS)*

The risks involved with nuclear power have been compared to that of climate change or economic risks especially after the Fukushima disaster (Froggatt et al., 2012). On top of this a shortage of skilled workers combined with a lack of transparency in safety management has brought nuclear safety high on the public agenda (Teravainen et al., 2011). If nuclear safety can be seen as a current concern, then any lack of skills for the nuclear industry would likely exacerbate this concern.

Interviewee 6 represents one of the 6 main centralised energy utility companies, which only goes to confirm the statement, as the quote may be seen as an issue for nuclear energy's security. This means that with decentralised electricity the UK would become less reliant on importing knowledge and skills from other countries (although not completely removed as a decentralised electricity system include more than just micro generation, it can include community scale projects and may require increased activity for the network operators). The cost of importing skills and knowledge is likely to be higher and thus will increase the end cost to the consumer. A highly decentralised electricity system can utilise the current UK skills base. This can have a knock on effect for the UK in developing a larger number of jobs rather than needing to import a small number of highly skilled individuals.

The impact the skills and knowledge base of a particular electricity system can have a direct impact on the flexibility and on the economy. A decentralised electricity system, with its larger number of potentially domestic skills which are arguably easier to find will mean the skills required can be adapted to the changes of the electricity system. In addition to this these larger numbers of lower level skills found in a decentralised electricity system would also provide a benefit to the economy though the generation of local jobs. This is a positive indicator for a decentralised electricity system. However in order to capitalise on this, the rules and incentives, which make up the governance of the electricity system, would need to ensure the skills and knowledge of the low carbon future can not only be found but benefit the economy.

8.4 Summary

Common concerns for future energy security made by research participants are the impacts of the European Environmental policies (the LCPD and the IED). These directives dictate that a large amount of generating capacity will be required to close within the next decade. There is a requirement to fill this loss in capacity. The use of centralised generating plants for developing a low carbon future provides doubt over the ability for low carbon centralised plants such as nuclear to be built and operational in the restricted time scales. This provides two options: firstly, to continue down the fossil fuel route using mainly gas generation to fill capacity gaps and creating the risk that carbon targets will not be met. Or secondly, to invest in small-scale renewable generation, which will initially need Government support.

The timescale factor is important to the governance of an electricity system due to governances' cyclical nature. The rules and incentives for a decentralised electricity system will need to be in place well in advance in order to develop the role of stakeholders and actors. The concern over time scales has lead to two separate points: The time it takes to move from a centralised to a decentralised system in terms of developing the technology and the timescale in the time it takes for the system needs to change, to meet carbon and capacity requirements. One perception of a group of research participants was that a change in the system poses very little threat to security as long as it is a gradual change in which the whole system could adapt.

One of the main impacts the stakeholders identified from the move to a decentralised electricity system is on the type and number of skilled professionals. It is likely that a low carbon centralised electricity system would require an increase in the number of lower level skills such as plumbers and electricians for the installation of small scale generation. Further to this the stakeholders identified that a low carbon centralised electricity system (research participants often discussed nuclear as the main low carbon centralised technology) is likely to require more higher level skills for building and operation of generation plants which are likely to require international help.

A counter argument which was made is that even in a decentralised electricity system there is likely to be a number of high level skills required for the decommissioning of the current nuclear plants. Therefore, a fully decentralised electricity system will always require some highly skilled professionals in order to maintain it. However, the point to make is that it promotes more employment which can be developed in the UK.

The issue is that there needs to be a clear drive and focus for the required skills to emerge. Without strong government direction any change to the electricity system may suffer a lack of skills.

Another interesting point to make here is the link between skills and investment. The required skills are needed before the investment is put in place. However, the Project Discovery report by Ofgem (2010a) states that the availability of skills can be a barrier to the rapid deployment of low carbon technologies. The skills would be unlikely to occur without the demand (meaning the investment) being in place.

The availability of appropriate skills will be an important factor in ensuring the secure operation of the electricity system, whether centralised or decentralised, as recognised by both Government and industry. However, little concrete policy has been developed to provide skills appropriate for a more decentralised system. While skills are being developed on an informal level for microgeneration, there are still concerns about the availability of skills for larger scale decentralised installations which should be addressed. Finally, any change to the electricity systems, processes, and organisational bodies will incur costs.

The requirement for low carbon generation in the UK ensuring the system will have to change. The discussion here is, would a decentralised electricity system cost more than a centralised system? Any change to the current system, especially on a scale of moving to a decentralised system could have a large impact. It is likely that change will inherently bring with it additional costs. Changing the system of generation to a decentralisation will be likely to attract additional investment for the private sector. This will be discussed in the next chapter.

9 Investment for a Low Carbon Secure Future

The previous chapter looked at the issues surrounding the move to a low carbon future, specifically concerns over the timescales of such a move. The timescales are constrained by the policies, goals and targets which direct the electricity system. It was apparent that most of the interviewees identified that the closures resulting from European Directives, the LCPD and IED, would have the greatest impact on the short to medium term security, specifically the level of capacity for the UK electricity system. This means that any replacement generation would need to be found within a specific timeframe. The impact of this is, the governance of the electricity system will need to promote the move to a low carbon system, at the same time ensuring its stability so that energy security is not compromised.

The governance of a secure electricity system in part means ensuring the right investment is in place for the future. For the UK electricity system this means delivering low carbon generation on top of this. The governance will need include the right rules and incentives to ensure the generation and delivery of electricity is achieved. Additionally, it will need to ensure the right actors are involved to provide the investment.

This governance process will obviously differ depending on whether the future is centralised or decentralised. Chapter 9 will identify how a decentralised electricity system will impact on the investment portfolio and ultimately the role of investment in ensuring energy security in the future. It will do this by establishing how different stakeholders view the impact of decentralised generation and explore the different perceptions of how the various stakeholders may impact on future development. A decentralised electricity system not only means a larger number of smaller generating plants but also a change to the type and 'scale' of investor. It involves the introduction of a large number of smaller electricity investors from householders, businesses and industry who, as investors, previously would not have existed. Therefore, a decentralised electricity system would provide a different avenue for investment. This style of investment could also contribute to developing the distribution network to support decentralised electricity with the advantage of greater efficiency and security of that network.

However, the issue here is not simply one of security, in order to meet the UK's carbon targets, the replacement generation will have to consist of a high proportion of low carbon generation which, should be capable of being built quickly. The issue for the large power stations is that the lead-times can prove to be very long (Schlissel and Biewald, 2008). Therefore, not only is a large injection of investment required for low carbon generation, it is also needed for the right technology which can provide for the future of the electricity system.

The UK electricity system is constantly changing and adapting to its immediate and predicted requirements, however the rate of change could be considered slow. These changes are directed and governed by the rules, incentives and the interactions between system actors. Hypothetically, in a completely open and competitive market place, the majority of the investment would go towards the technology offering the highest returns and lowest risk. However, it would be unlikely for the market to deliver the additional requirements on the system such as low carbon objectives and addressing fuel poverty without external influence such as Government policies and subsidies (IPCC, 2014). Therefore, the governance of the energy system has a direct impact on the ability to find appropriate investment for a low carbon, secure future.

9.1 What investment is needed?

Ofgem has estimated that up to £200bn of investment could be required by 2020 in order to meet the dual requirements of climate change and energy security. This is required in the face of huge global demand for investment, unknown future costs of commodities, and the continuing impacts brought on by the global financial crisis. Of this estimate, £32bn has been set out for the distribution and transmission and £70.5bn for new electricity generation (Ofgem; 2010a). Other issues highlighted by Ofgem include the uncertainty of future carbon prices, dependence on international markets, the impact of increased costs to the economy and the issue that short-term pricing signals are not able to reflect the value customers place on electricity. This means that peak electricity supply incentives are not strong enough to impact on investment in the short-term (Ofgem, 2010a). However, since then the Electricity Market Reform has been rolled out which includes a mechanism designed specifically to incentivise investment into ensuring peak demand is met (DECC, 2013h).

The Government's policies and goals for the UK electricity system have a large influence on its long-term future pathway. This long-term investment within the electricity system is often influenced by the UK's targets for meeting climate change and the on-going requirement for a secure electricity system that has been set by Government. One of the main challenges is to find the balance between the right amount of incentive for investment without causing excessive additional costs to the consumer and the industry. In addition to this the market mechanisms must be able to attract the required finance for the medium and long-term without compromising the existing and on-going investments (Ofgem, 2010a). An example of this would be trying to solve a short-term capacity issue by building new coal fired power station, which would undermine the longer-term goal of a low carbon future. Therefore, the incentives need to be set out, providing the investors with the ability to calculate their investment.

Interviewee 27, a civil society actor, identified the importance for any investor to be able to calculate the risks of investing in the electricity sector over any alternatives whether they are for a low carbon centralised or decentralised future.

> *"I think a lot of investors are reluctant to make decisions until they know exactly what the financial outcomes are."*
> *(Interviewee 27 CSBS)*

Although interviewee 27 does not identify the Government role as setting out the financial return of a project, they do have a part to play in setting policy framework for the incentives and market mechanisms. This would indicate that clear direction from Government, is necessary in order that investors can calculate the perceived reduced level of risk. This idea was backed up by E.ON in the 2011 Energy Security or Independence Consultation:

> *Policy uncertainty could lead to a hiatus in investment. (E.ON, 2011)*

This implies that the UK Government plays a key role in the governance of the UK electricity system. However, as identified in section 6.3.1 governance theory suggests the electricity system is operated by a network of stakeholders and therefore, investment needs to be the responsibility of these stakeholders and not simply the UK Government.

Since these interviews were undertaken, the Government has identified, through the EMR, support for both renewable generation and nuclear generation with the contract for difference. However, as identified in section 2.2.1, the different set up of the nuclear (baseload) CfDs could signify a preference to nuclear generation.

The Government's promotion of the UK electricity sector can have two different modes: the market and market mechanisms designed for electricity generation and supply companies, and the regulatory approach of the electricity transportation monopolies. The investment strategies into each are different and therefore this chapter has been split, firstly into the investment under regulation, looking at the distribution and transmission networks. Secondly, the generation sector, focussing on future capacity levels, the importance of natural gas in transitioning to a decentralised electricity system, the wholesale market approach and finally the changes decentralised electricity would bring to the number and type of investors.

9.2 Network Investment

The Government is trying to address investment concerns around building new forms of generation through the Electricity Market Reform (EMR) package (DECC, 2011a). Investment in to the electricity networks (both transmission and distribution) is organised through the regulation of the TNOs and DNOs. This means the governance of these networks is controlled by Ofgem and the future of the networks will depend on the set up of RIIO (see section 2.3).

The electricity networks are seen as natural monopolies, where in a similar way to the regional water supply companies, they need to be operated by a single organisation, without realistically being able to introduce competition. Investment has to be enabled through regulated mechanisms. Expenditure into the networks is framed by the price control period (see section 2.3). However, additional mechanisms such as the Network Innovation Competitions (NIC) and the Low Carbon Network Fund (LCN) are designed to provide funding for research, development and trials for new technology, operating and commercial arrangements (Ofgem, 2012e). This section will set out whether sufficient investment in networks would be forthcoming in a decentralised electricity system.

The difficulties in finding the required investment for the networks will also be shaped by the regulatory strategy adopted. Regulation to encourage the deployment of small-scale generation will differ from the regulatory framework required for a system dominated by large scale generating plant (Chapter 4). A system centred around small-scale generation could result in an increase in intermittent renewable generation and the possibility of the distribution networks becoming more active. This in turn will require technology and training for managing the networks in a more active way. Another aspect to discuss is the increase in demand from the electrification of heat and transport sectors. A third aspect to look at is the impact on the high voltage networks, such as the transmission system (Ofgem, 2010b).

9.2.1 Future of Transmission Network Investment

Originally the electricity system would have been made up of groups of local networks feeding the local area. The transmission system was designed to connect these individual local distribution networks, allowing the introduction of larger power plants and connect supplier and consumers over longer distances. This allowed both the exploitation of economies of scale in power plants also an enhanced degree of security as power could flow from small individual networks to others. Over time, the distribution networks moved from active operation to being passive recipients of power from the transmission network. With most generation connected at transmission level. Very little power is now injected onto the transmission system from distribution networks. The increase in decentralised electricity generation may have a direct impact on control of the system.

This centralised design of the electricity system was identified by identified by a number of the participants and shown by interviewee 12 and 11 (a civil society based stakeholder and regulatory based stakeholder respectively).

> *"The networks have been designed from a centralised point of view to push electricity one way, from big plant down through a load of wires until it hits your home." (Interviewee 12 CSBS)*

> *"If we are going to be relying more on low carbon decentralised energy then the networks become a factor in security, so in themselves they are not a security issue, you just need different networks in order to deal with the security issue" (Interviewee 11 RBS)*

Interviewee 12 and 11 indicate certain issues in moving to a decentralised electricity system for energy security. Without the modification of the electricity supply network a future decentralised electricity system could see the electricity networks having a negative impact on security. Without an increase in investment into network development the concern is that, as the generation on the distributed network reaches a tipping point, there may be a requirement to feed the excess capacity back up the system.

Although, the regulatory based stakeholder, Interviewee 11, is not discussing the transmission system specifically they do make the point that the networks in general are not currently seen as a factor in energy security, therefore identifying the network owners as having no responsibility of energy security at present. However, this is not the opinion of all regulatory based stakeholders.

An opposing point of view was published from CE Electric, a network operator, in the EMR consultation identified that its participation in the electricity industry means it has a role in ensuring energy security:

> *Although CE does not have investment in electricity generation assets, it considers that it has a relevant contribution to make to this consultation on two grounds. CE has a clear interest as a significant participant in the electricity industry in helping to ensure that the electricity market provides adequate incentives for generation capacity, but since it has no investment in generation it can bring a knowledgeable but impartial perspective to solving this problem. (CE Electric, 2010)*

This is a conflict of ideas over the perception of network owners' role and responsibilities. This will be discussed further in chapter 10.3. However, the investment of the electricity networks will be vital to the future of a low carbon electricity system.

Some of the changes to the transmission network (as a result of increased decentralised electricity) will result from the development of the distribution network, mainly from an increase in generation on the local networks and the possibility that they will become more active as discussed in section 3.2.2 where the DNO would have to balance their own network. Therefore, the transmission network is likely to require a change to its technology and operation (in terms of accepting power flows from the distribution networks) for a decentralised electricity system which will require additional investment. As long as this technological change is seen as possible from an engineering point of view. It is then a question of how long the engineering may take to install and whether it would be impeded from a financial or economic constraint.

Two regulatory based stakeholders, Interviewees 17 and 11, may provide the answer to this. They discuss the network development as reflecting generation and the 'demand' for generation, which is driven by market arrangements:

“…..the networks that we build respond to a free market so we have to take a view on what solution the market will come up with” (Interviewee 17 RBS)

“The [distribution] companies will grow in capability in parallel with the demand” (Interviewee 11 RBS)

The idea that networks will respond to whatever the market provides is an interesting aspect for governance and transition theory. This identifies the coevolution discussed in section 6.2.2. The transition to a low carbon system requires the stakeholders not only to work together but also develop at a similar rate as certain aspects will be dependant on each other. Small-scale generation requiring the DNO to provide access for connection in some cases will mean upgrading of surrounding network.

The governance of the transmission system operator and the distributed network operators are managed through the regulator, Ofgem. This would suggest that the regulator’s objective would be to ensure the network’s development follows a similar pattern with the level, location and type of generation and demand on the system.

The two network operators quoted above identify that they do not see a concern for the security of their networks in a decentralised electricity system. However, the reality is that it will be down to the regulator, Ofgem as well as the rules and incentives which develop the electricity networks to ensure a decentralised electricity system can contribute to energy security. This was identified by interviewee 5 who indicates that each actor group has its own responsibility for energy security.

Short term operational security it is national grid. At a slightly more nebulas level it is the market and Ofgem as the regulator has a duty. Then at a political level the energy minister. Interviewee 5 GBS

9.2.2 Increased Generation On Distribution Network

As discussed in chapter 5 there are implications of increasing the level of decentralised electricity generation on the electricity system. For the distributed network operators this would mean handling an increased amount of generation on their networks. Much of the current, low volume of generation connected to the distribution network can be considered ‘invisible’ to the network owners, as they do not have the technology to know the different flows of electricity that close to the point of generation (Ofgem, 2007c). Instead it is absorbed by the level of demand in the local area and therefore often considered as *"negative load"* (Interviewee 11, a regulatory based stakeholder). However, a significant increase in the level of distributed generation would change the invisible, negative load to one which requires management and therefore, a change to the DNO's operations, as a result further investment into the network may be required.

One of the issues surrounding this was identified by interviewee 18, remarking over the increased costs involved an active distribution network:

> *"The more decentralised it becomes the more you have to make a distribution network work like a transmission network. You are balancing within that system rather than at a higher level and that clearly becomes more expensive the more decentralised it becomes" (Interviewee 18 MBS)*

This market based stakeholder (interviewee 18 quoted above), from one of the big six energy suppliers, considers that balancing the system closer to the point of use is more costly than balancing on the transmission network.

The rise in distribution network's cost is partly a result of the additional connections to the network, but mainly the implications from changing the use of the distribution network from its previous design criteria. This increases complexity, which is likely to make the operation of the distribution network more expensive(Clastres, 2011). Moving from a passive transportation system delivering electricity from the transmission network to the consumer, to a more active role, which may mean having to balance the generation and demand on its networks (DECC, 2012k) (as discussed in section 3.2.3).

However, this may not be the case, a counter point made by interviewee 27 a civil society stakeholder, is the reduction of investment requirements for transmission networks. The use of decentralised generation could mean a lower capacity requirement for the transmission network, as power flows are increasingly concentrated in distribution networks and therefore lower associated expansion or reinforcement costs at the transmission level (Chmutina and Goodier, 2014). However, this may have not have the desired effect, there is a possibility that, as a result of reduced level of 'traffic' on the transmission networks the transmission network owner (TNO) would have reduced income thereby penalising the TNOs who may request compensation.

In addition to this, further benefits from a decentralised future to the electricity network include: the changes to relatively inefficient current system where 5-8% of the electricity flowing through the distribution network is lost (Ofgem, 2012b). The siting of generation on distribution networks can reduce these losses, thereby improving the economic efficiency of the system as a whole (Parliament, 2011). One of the regulatory-based stakeholders discussed this economic aspect, identifying that an increase in decentralised electricity will attract the development of the network and release its currently unused economic value (interviewee 11). The increase in generation on the distribution network as a benefit to the local grid was also discussed by interviewee 3, a market stakeholder. This is an indication of the complexity of calculating future costs with such a vast change to the electricity system. Without being able to accurately calculate costs, investors may be cagey about investing in new projects, which in turn could impact on energy security.

9.2.3 Decentralisation and Smarter Grids

The move to a smart or active network has been identified by DECC and Ofgem in the smart grids forum to reduce costs through a more efficient network operation, support economic growth and increase energy security (DECC and Ofgem, 2014). The majority of the losses in the delivery of electricity are found in the distribution networks and losses mean reduced efficiency and higher costs. Utilising an active network operation for the DNOs means that the distribution network is opened up for increased amounts of decentralised generation and increased efficiency on the networks.

The complexity and multifaceted nature of the electricity system, discussed earlier, is suggested in this quote from SSE in the “UK's Energy Supply: Security or Independence?” consultation.

> *In terms of distribution there is a role for more effective and dynamic distribution networks that manage demand more effectively and enable a larger amount of decentralised energy to generate. These smart grids could have a major impact in terms of minimising new infrastructure costs by using assets as effectively as possible, whilst reducing overall demand*

thereby reducing the UK's reliance on, and exposure to, imported fuels. (SSE, 2011b)

The move to a more active or smart system is also complicated by the concept having different meanings for different groups. One regulatory-based stakeholder (interviewee 11) provides a good explanation; if the distribution networks are passive then the transmission network would be considered active. The transmission networks have been active for many years, which means the control technology can be rolled out in order to balance supply and demand in real time.

"A smart network is the one that is actually giving choice to its users". (Interviewee 11 RBS)

However, an additional discussion which arose over whether the DNO's would want to be involved. Interviewee been identified it as a matter of economics. What this shows is, that the incentives will need to be in place.

"The DNO's would be happy to become active as long at the money is there." (Interviewee 30 CSBS)

"Technically, it just needs to make sure that the right incentives are put in place for the decentralised providers of energy to offer the services needed to run a stable grid." (Interviewee 3 MBS)

Ensuring the right incentives are in place for the electricity networks should in theory simply be a matter of setting the right regulation. Interviewee 12 identifies this regulation of the electricity system as "low risk".

"[Currently] pension funds effectively own a lot of the networks because it is seen as low risk and rather dull, they are always going to be there, long-term assets, everyone is happy, it's a regulated price." (Interviewee 12 CSBS)

Therefore, setting the incentives for a low carbon decentralised future could be considered as low risk for the current distribution network operators. However, interviewee 12 also reflected that the increase in activity would change the operation of the electricity networks. This was also identified by interviewee 6.

However, with a higher level of activity on the networks you could be asking a section of the value chain effectively to do something that is completely outside of its comfort zone" (Interviewee 12 CSBS)

"Where does the investment into networks come from? Obviously it's the DNOs, which are regulated investments.

Therefore are there issues with the level and difficulty of investing in the networks because of regulation" (Interviewee 6 MBS)

This concern was also shared by one of the government-based stakeholders (interviewee 22) where the understanding, knowledge and skills required to regulate a decentralised electricity will likely be very different than it is today, especially for the distribution system.

"I was also thinking [...] do we have the skills to regulate a very decentralised system" (Interviewee 22 GBS)

If Ofgem, as a major player in the governance of the electricity system, is seen as promoting a centralised future over decentralisation, coupled with DECC's apparent promotion of centralised technologies for energy security[26], there could be a serious problem for the development of a decentralised electricity system. This will be discussed further in section 10.1.2.

There are two aspects for the regulation of a decentralised electricity system to consider. Firstly decentralisation may bring an unknown factor, i.e. how much generation is there going to be in a specific location and therefore, how much reinforcement will be required for that network. Secondly, with an increase in distributed generation there comes a point where the network will need to become smarter and more active similar to the transmission system operation (see section 3.2.3). This will mean a much larger level of investment will be required which will eventually be passed on to the end consumer.

The understanding that the investment for the networks can be found through regulation (see section 2.3) does not provide the whole picture. The current electricity system, even without the requirement to move to a low carbon future, would still require investment into the networks. This is due to the degradation of the current network and its requirement for replacement and the upgrades from an increase in demand. However, by increasing the level of generation connected to the distribution network, not only does the required investment increase, as does future complexity of managing the networks (DECC, 2012r). Therefore, regulation can drive investment, either through requiring it or, as is the intention

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[26] *As can be seen in the ESS (see section 4.1.6) and through the capacity market (see section 2.2.2)*

behind RIIO as discussed in section 2.3.1, by providing incentives to guide the decisions of the DNOs.

The future of the DNO will likely see a great level of activity. For the DNO to become active it is clear that there would be operational costs incurred, but also efficiency savings and benefits towards energy security. Having said this the pricing signals with the smart grids would need to be developed to reduce peak loads. Simply reducing overall demand may not reduce reliance on fossil fuels unless the peak demand is cut.

The move to a smarter network is not dependant on a decentralised electricity system. It can however, be considered a pre-requisite to handle the larger amount of generation. The future is likely to see higher levels of demand (see section 3.2.1) thereby requiring a more active DNO in a decentralised or centralised electricity system.

9.3 Investment in Generation

Investment into the electricity system can be considered a major catalyst and indicator of the UK's progress towards a low carbon system. As discussed in chapter 2 the low carbon electricity system could develop along two separate pathways: either a centralised system dominated by an increase in nuclear generation and fossil fuels with carbon capture and storage rolled out on a large scale, or a decentralised system, utilising significant levels of renewables and demand management technologies with storage solutions. There are many distinctions between the two approaches, social, political, technological, but often, the comparisons made between them is economic.

The approach of focusing on the quantifiable economic aspects of policies is frequently made by Government (DTI, 1999; 2000; 2002; 2003; 2006b; 2007a; DECC, 2011d; 2012d; 2012g; 2013d). However, the complexity of the electricity system and the multifaceted nature of a broad definition of energy security means that by looking purely at the relative costs may not provide the best results. The additional benefits of decentralisation would not be taken into consideration, such as the increased ability to involve the consumer in the energy system.

This perspective also extends to the additional factors which play out in the investment into new generation. A comparison of decentralised against centralised electricity systems could include the different investors which would be included in the process it should also discuss: the difficulty in finding the investment and investors, the future costs of generating electricity and its predictability, and the avoidable costs which comes with a new system compared with maintaining the current configuration. This section will begin by looking at the capacity concerns for the future electricity system to establish what investment is required. It will then look at investment into gas fired generation as it is widely considered as a 'transition fuel' for the move to a low carbon secure future. It will then discuss the stakeholders' perceptions of the market system for security. One of the biggest changes a decentralised electricity system could bring is a shift in the stakeholders and the type of investor that could operate within. Finally, this section will look at the stakeholder perceptions of how investors will change and how this may impact on energy security.

9.3.1 Confidence in Future Generation Investment

The move to a low carbon electricity future will likely mean a very different generation portfolio than there is today. According to DECC the GB electricity system is due to lose a 20-25% of the generating capacity from the closure of fossil fuel and nuclear power plants over the next decade (DECC, 2013h) (see section 2.5.1). A reduction in capacity causes serious concerns over the supply-demand margins and increases the likelihood of blackouts, which can in turn cause an increase to the cost of electricity and impact negatively on the economy (Ofgem, 2012h) (see section 2.5.2).

The significance of these impacts from a loss in capacity raises the question of the extent to which the UK Government will go to try to ensure the capacity is retained. Interviewee 3 a market based stakeholder suggests that the general public would have serious issues, if there was not enough generation to meet demand and especially if this was down to Government policies:

> *People will start screaming sometime before saying "its ridiculous we're closing these hardly used power stations that run 10 days a year because of that certain directive so it means the lights are going to go out on 5 days a year". So I think if it did come to the crunch something will be done if plant wasn't actually built to replace it." (interviewee 3 MBS)*

As discussed earlier, the EU's Large Combustion Plant Directive and the Industrial Emissions Directive will contribute to much of the closure of the coal fired power stations. However, many of the research participants in this thesis raised the possibility these policies may be downgraded if they pose a threat to the security of the UK energy system, on the basis that, if security is the most important challenge to the electricity system (especially in the current economic climate), any policy or mechanism that would impact seriously on security could be re-addressed.

The idea that the UK Government would not follow through on its policies and directives identifies an interesting aspect of the relationship of Government and the market stakeholders. It identifies a possible lack of trust in Government to deliver on its statements and policies and that security is seen as paramount above a low carbon future even through there is a very strong argument to say that the Government would not be able to get any kind of derogation from the directives. When discussing this with a government stakeholder (interviewee, 5), the notion of a derogation of EU policy would not be possible; the directives are set in law and therefore not able to change. Further to this the coal fired power plants would begin to increase their running hours up to the deadline in order to close early. This would allow them to be broken into parts for use on other power stations. Therefore if the directive was changed so the plant did not have to close they would not be able to reuse the power plant components, if they are required at a later date. In addition to this, investment into supplementary generation would have already begun. This investment would have been made with the understanding that a certain number of coal-fired power stations would be closed by 2016 (National Grid, 2007). If the directives were not enforced, investment into new generation would be undermined and create distrust in Government policy for future investment.

The belief that Government may try to go back on the EU directive, when there is strong evidence to suggest this will not and cannot happen, could be an indication that there is a lack of trust in Government. Any lack of trust in Government could cause problems for large-scale investments which are competing with other international projects. Alternatively the reason for this could be that they believe the future security of supply is under such a threat that there is no option but to find a derogation. This may be due also to a lack of investment in new technology. This was identified by E.ON in the Energy security or Independence Consultation and backed up by interviewee 30.

> *Given the challenges the UK faces and the long timescales of many infrastructure developments, policy certainty [...] should be a priority for Government (E.ON, 2011)*

> *"I think the biggest security concern is the lack of clarity on Government policy" Interviewee 30 CSBS*

Once again here is another market-based stakeholder indicating that it is Government who needs to ensure through clear policy the future of the electricity system. It is the market-based stakeholder who would be looking for a solid indication of the future of the energy system which could mean incentive for a particular technology type. This would indicate a requirement for Government involvement in a market-based electricity system.

Since these interviews the UK Government has given further detail to the Capacity Market identifying how they believe capacity will be found. However, a point to make here is that it could be argued that the stakeholders look to Government to ensure the short-term security of supply. The majority of the research participants identified Government as responsible for setting out how security is delivered. The issue with this is that Government does not always deliver policy certainty as identified by E.On above. Uncertainty transfers to risk, which means, without higher returns, a reduction in investment.

This idea of policy certainty can also be displayed through the distrust in politicians' ulterior motives. This trust in Government not only needs to be in place for the policies they implement but also for their modelling of the future. Interviewee 8 demonstrated distrust in certain predictions over future capacity concerns:

> *Saying you will run short of electricity oil or gas I would say that is probably just a flag that people wave to support a lobbying organisation…….The politicians screaming about a supply gap or generation gap is bullshit really. But they use it to promote whatever pet project they have on. (interviewee 8 GBS)*

Concerns about future capacity are augmented by the potential impacts from the increased electrification of the heating and transport sectors. Government has identified concern over the rise in demand levels (DECC, 2011a). However, a rise in demand may not be a severe as Government suggests. There is no guarantee over the electrification of heat and transport and advances in energy efficiency for the household and businesses could relieve much of the demand increase.

Decentralised electricity generation provides a direct link from the electricity system to a large number of smaller stakeholders many of who are consumers. This can have a positive impact on the behaviour of these consumers. It also has a close link with the implementation of smarter networks for balancing the distribution system, thus further benefiting efficiency. In addition to this, by increasing the level of decentralised electricity generation the capacity level can grow in a short space of time and alongside the increase in demand. Small-scale, decentralised electricity generation has, in general, short lead times from design stage to being operational. This means that it has the potential to fill future capacity gaps and impact positively on future energy security (Sambeek, 2000).

However there was concern over whether a low carbon decentralised electricity system could replace the current centralised system.

> *"Particularly with the renewable side [...] I think people are quite naive in believing that we can scale up an industry which is still a very nascent immature industry and deliver reliable construction and operation into the medium term and we risk tipping a huge amount of money into that." (Interviewee 31 CSBS)*

Interviewee 31 went on to discuss the absence of the required knowledge and skills for operating and maintaining such a plant:

> *"We don't have a scaled up O&M supply chain. Insurance is a really difficult issue. There are so many risks, which there is no actual evidence to assess. The robustness of the technology is largely unproven" (Interviewee 31 CSBS)*

However, the development of the skills required for small-scale renewable generation can be perceived as easier, compared to for example, the nuclear power industry see section 8.3 for further information and discussion. As discussed by a market-based stakeholder (interviewee 6).

> *"if you take it back to its first principles, you need engineers who are competent in engineering and you would argue that we have a better skills base in this country to deal with renewables than we do with nuclear, because we have not done nuclear for ages other than keeping the existing ones running. But we are planning to build 6-7 new nuclear power stations." (Interviewee 6 MBS)*

Interestingly this market based stakeholder represents a company who were planning a joint venture to build a new nuclear power plant, however, in 2012 their venture was halted and they sold all their sites earmarked for nuclear power plants.

Not only this, decentralised generation may also provide an additional boost to the economy by the creation of jobs within the UK, rather than a requirement for a more expensive skilled knowledge base found outside the UK as discussed in section 5.1.3.

9.3.2 Investment risk comparing centralised to decentralised Generation.

When looking purely at investment funding, there was clear concern amongst many of the interviewees that the risk involved with large-scale investments is high. This risk is associated with pinning a large sum of money on a single project, which if it fails due to policy changes, project management error or technical failure, there could be catastrophic financial repercussions. Here is a list of quotations from various interviewees showing a feeling of large scale investments being a risky business.

> *"Very large projects can be quite risky things, particularly if you want to build some nuclear power stations at the moment" Interviewee 3 MBS*

> *The nuclear generators are tax payer subsidised and considered too large to fail, which makes me very uncomfortable. Interviewee 8 GBS*

> *"I think particularly with the financial markets the way they are at the moment, it is very risky business for these people to dabble into large investments" Interviewee 9 CSBS*

> *"I think it is really hard to call because, putting a large sum of money behind a large project is a pretty risky thing to do. You can lose a lot of money if that project fails. Whereas if you are investing in a lot of small projects, then that is much less risky." Interviewee 22 GBS*

> *In the future gas, oil and coal are going to be more expensive wherever you source them from which will have some impact on a macro economic level. From that perspective renewable energy will have a significant impact. Interviewee 8 GBS*

> *Nuclear is an interesting component to the low carbon mix. I believe in running existing plants as hard as we can because*

effectively threat is a sunk investment. For new investment I don't think the economic arguments stack up. You are mortgaging future costs very strongly against cheaper electricity now, by passing the bill for decommissioning. Interviewee 8 GBS

The small collection of quotes from the interview process are representation of the different stakeholder groups. With the exception of interviewee 3, each of these research participants could be considered as aligned with the promotion of small-scale electricity generation.

In addition to this interviewee 11, a regulatory stakeholder, identified that in order to find the investment in large-scale generation, the risk would need to be lower relative to the small-scale. This is because; with such a large level of investment the investors would require convincing.

"The risk to the investor has got to be reduced if you want to be convinced that we are going to get a couple of hundred billion poured in on building new power stations" (interviewee 11 RBS)

Therefore it could be argued that in order for a low carbon centralised system to be implemented, it could require greater financial aid. Thereby, meaning greater costs to the consumer impacting negatively on energy security. Further to this, a government-based stakeholder identified the difficulties a centralised electricity system has in terms of finding investors. The type of investor for a centralised generation plant is likely to have interests outside the UK. Therefore, the investment portfolio will be competing with other countries:

"most of the companies who operate in the UK now are international companies. Clearly they have a choice in where they do invest. If you are Eon do you invest in Germany do you invest in the UK? Things such as regulatory uncertainty would undoubtedly drive investment abroad." Interviewee 13 GBS

This identifies that some investors and some Government players view large scale, low carbon generation as a risky investment and requires higher returns. This has been reiterated recently with the subsidy for nuclear power where they have been guaranteed above and beyond the market price for electricity at £92.50 per MW (DECC, 2013n) twice the current market price of electricity. Although the strike prices for renewables are also set they have a shorter guaranteed contract length and are subject to a more adjustable reference price (see section 2.2.1).

However, this was not the response from all research participants. Interviewee 31 a civil society based stakeholder has a counter argument regarding the ability for the smaller groups to find competitive investment.

> *At the moment investment into energy projects are made by large companies with good credit ratings. Once you consider that down to a more local level the ability of individuals, small businesses and communities to raise finance at competitive rates with what could be raised by an international is quadrupled (Interviewee 31 CSBS)*

These are very open comments on the nature of the investment at the moment. They discuss the ideas around the risk in terms of scale; yet, the risks, which need to be identified with investment into building generation capacity, are far more complex.

The risks involved in investing in new generation fall into several categories. Firstly, the costs of building the plant, including the consultation fees such as planning, design, engineering and environmental considerations. Secondly, the period of time the plant is likely to be open and the ensuing maintenance costs. Thirdly, the price received on the market for electricity, including any additional subsidies. Lastly the running costs including operation, maintenance and cost of fuel (Gerwen, 2006).

As discussed in section 5.1.2 there are two types of expense associated with any electricity generating plant; the fixed and the variable costs. Table 9-1 shows the consumption and generation costs for a variety of types of plant. The variable costs indicate a level of uncertainty in the building of such a plant and therefore the risks involved. For most renewable energy developments almost all of the costs are related to the capital costs of construction. Once built, there are no fuel costs (apart from Biomass) and mostly low operation and maintenance costs (Laing & Grubb, 2010). This is in sharp contrast with conventional generation where the fuel costs dominate the generation costs associated with it as shown in Figure 9-1. This does not identify the maintenance costs to offshore wind, which are likely to be much higher than onshore wind, due to the difficulty of maintaining turbines in a hostile environment.

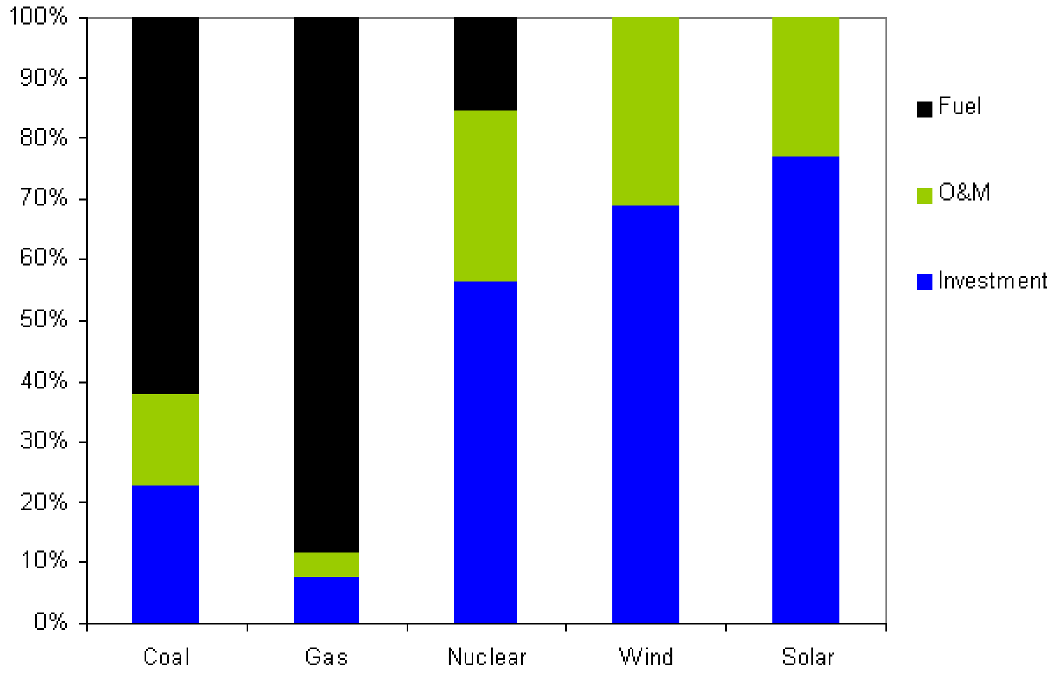

Figure 9-1 Composition of generation costs (Laing and Grubb, 2010)

Table 9-1 Characterisation of costs for DG and RES - timing of expense (Gerwen, 2006)

Type of Expense	Initial	Continuing
Fixed	Engineering cost Investments Licensing cost MW-based connection cost Metering	MW-based distribution tariffs Fixed taxes Scheduled maintenance Insurance
Variable	MWh-based connection cost	Unscheduled maintenance Fuel cost Fuel taxes MWh-based distribution tariffs

The running costs of each plant is arguably far easier to estimate for a small-scale and, specifically, for a renewable generation plant. With the renewable generation plant, it is mainly the cost of the operation and maintenance fees, which can be defined early on in the project. The revenue of the project would hinge on two factors. Firstly, the output of the plant, which includes time and level of power generation. Using the example of a single wind turbine, the wind strength is a major factor in the time and output of the generating station. Single day forecasting of generation is understandably very difficult, however, the forecasting period ran for over a year a more reliable outcome could be achieved (Pinson et al., 2007). The second factor is the price it would receive on the market. This may become more stable as a result of the introduction of the EMR namely the contracts for difference (DECC, 2013h).

The volatility in price for fossil fuels separates renewables from conventional generation and provides an additional unknown factor in the running costs of the current centralised plant. In comparison to a renewable energy system the fluctuating price of international gas, oil and coal mean it is very difficult to predict how much it will cost in the future. At the moment the cost of electricity is closely linked to the price of oil and gas. This is because of the dominance fossil fuels have on the market. However, in a low carbon system fossil fuels will have a reduced impact unless carbon capture and storage is implemented on a large-scale. The volatility of fossil fuels is an example of this and their future is uncertain. The impact of this can be seen in the quote from a market player who specifically operates renewable generation technologies.

> *"One comment to [...] make is that we have been able to freeze our prices on two occasions in the last six months at a time when all the other big suppliers have been putting them up by about 9%. That's because of the way we source our energy. Because it is a secure reliable source of energy in that sense compared to [fossil fuels]." Interviewee 15 MBS*

9.3.3 Future of Gas Investment

In order to fill the capacity, that is due to go offline over the next decade (see section 2.5.2), investment will be needed for new, long term low carbon generation but also for technologies which will be able to act as a replacement in a short time-scale. One option for this is to construct combined cycle gas turbines (CCGT) plants that require relatively short lead times and they are highly flexible in operation, which makes it an effective balancer for inflexible or variable generation technologies.

Natural gas's benefits as a transitional fuel, stem from its flexibility, scalability and its reduced greenhouse gas and particulate emissions when compared to coal and oil (Stephenson et al., 2012). If natural gas is widely considered as the 'transitional fuel', bridging the gap between the current unsustainable energy system to the low carbon future required to combat climate change the next concern will be its availability and its cost (Stephenson et al., 2012, Skea et al. 2012).

> *Although global gas reserves remain plentiful, increased competition from emerging markets is likely to exacerbate price volatility in the UK and make access challenging. Global market developments could therefore have an influence on security of supply in the UK. (Energy UK, 2012)*

> *The UK's oil and gas reserves, whilst still significant, are no longer sufficient to meet domestic demand and it is therefore increasingly exposed to the volatility of the global fossil fuel market. (SSE, 2011b)*

The issue with natural gas is that it could mean a dependence on a single type of generation for this transitional purpose. This means that diversity and therefore energy security would be harmed as discussed in section 4.2.4.2. Another issue with natural gas is that UK supplies are dwindling and therefore the UK must rely on international supplies. As identified by Energy UK in the consultation on the role of gas and SSE in the Energy security or Independence Consultation above.

The concern over capacity levels is not just from the closure of certain generation plants, many of the CCGT power plants were built during the 'dash for gas' in the 1990s. Although they were built with a forty-year life span (Singh et al., 2011), they also require a major refurbishment at the half way point. This refit has been discussed as 'mid-lifeing' by interviewee 3 and requires significant investment in order to strip the plant down and renew a significant number of its components. Because of this significant investment, the utilities will have to decide whether to put the investment into the plant and have it run for another twenty years or to let it close.

> *"Obviously to put the investment in, they have got to be sure that there is a market for the generation from that plant" Interviewee 3 MBS*

> *"We are not seeing the scale of investment that is necessary because people are not confident that they can invest in […] gas assets because the fear is that you would not be rewarded economically" Interviewee 31 CSBS*

> *"The perceived future energy mix is often a large amount of renewable energy with nuclear to back it up. In the meantime new CCGTs will only come in with the balancing of wind. Therefore there is no investment environment for the CCGT as it has no major role." Interviewee 30 CSBS*
>
> *"I think we are surrounded by a huge uncertainty at the moment and there's a big uncertainty in the future of gas" Interviewee 25 MBS*

As can be identified from both market based stakeholder and the civil society based stakeholder there was a concern over the level of incentives to promote gas generation. These stakeholders represent both large scale, centralised systems (interviewee 3 and 31) and the smaller scale renewable companies (interviewee 30 and 25). The concern over ensuring investment for the CCGT can be explained by, as identified by interviewee 30, its role as a transitional fuel. Although interviewee 30 identifies its need in a renewable electricity future it is likely that it will also be beneficial towards a centralised low carbon future. Therefore, whether an actor is promoting a centralised or decentralised electricity future their goals to promote CCGT generation may well be aligned.

However, this mode of operation would change gas from its role from base-load to a peak load plant and require additional support in order to reduce the risk to investors. Generation plants which only operate at peak times, cannot guarantee when they will be operational and therefore operators cannot confidently predict the returns, making it more of a financial risk.

> *"I think the biggest security concern is the lack of clarity on Government policy" Interviewee 30 CSBS*
>
> *Uncertainty on the role of gas in the UK energy mix has also led to mothballing of existing plant and delays to potential new gas plant. It is therefore vital that Government, through long-term stable policies, including the introduction of a market-wide Capacity Mechanism, provides a framework for clear investment signals to the market. (Energy UK, 2012)*

Clarity is needed from Government to ensure that gas fired generation can be kept profitable in the future, low carbon system as identified by interviewee 30, a civil society stakeholder and by Energy UK in the consultation on the role of gas in the electricity market. If government is perceived as the lead stakeholder in the electricity system it is important that they set a clear and defined future for the role of gas.

9.3.4 Market involvement in investment

The UK Government identified in the Energy Security Strategy that it will focus its efforts on a competitive market (combined with regulation) to deliver energy security. This implies that the markets would be the main approach for finding the investment for a future of low carbon electricity generation.

From an economic point of view there are three aspects to consider when looking at investment opportunities in electricity generation: the upfront capital costs, the on-going running costs and the price the electricity will receive on the market. The investment scene for electricity is dominated by centralised technologies, in part because of the way in which the electricity markets are structured and regulated.

This also means that the current market price for electricity is dominated by the price of fossil fuels. This is because they cover the main share of the generation mix and are often the marginal plant in the market place (DECC, 2012h). The marginal plant is the lowest offer price in which capacity is met. As natural gas is the technology that often meets this lowest price, its price volatility nature can cause instability in the price of electricity in the market (Laing and Michael Grubb, 2010).

Other issues for decentralisation within the market at the moment include balancing and settlement complexities and the difficulties in entering the market faced by small to medium sized generators. One of these issues is the transaction costs, which, for the large scale generators can be reduced for bulk units. Also BETTA requires the generators to be able to predict their output, which, for many of the small-scale generators, being variable, makes this difficult (Woodman and Baker, 2008). Therefore, small-scale generators tend to sell to a third party through PPAs where they are often undervalued in an effort to compensate for the risks of intermittency and the high transaction costs per unit (Ofgem, 2008).

Finally, it is likely that for a renewable electricity future, there is a big question over whether the current market approach can deliver a low carbon future.

> *"If you were to implement an energy market system with the need for low carbon from scratch, then it would look very different than it does now" Interviewee 6 MBS*

> *"The problem comes if it's not a fair playing field because the market is set up entirely with centralised large companies in mind and doesn't really think about small players and the fact*

that small players may be just as efficient in terms of costs or may even be cheaper" Interviewee 21 GBS

"There has always been the question of whether the imbalance charges which come about from the market rules are accurately cost effective or they unduly discriminate thereby favouring the big players over the small ones" Interviewee 19 RBS

As discussed earlier, until the EMR there was currently little incentive for investing in gas purely as a back-up technology required for a low carbon future (DECC, 2011a; Helm, 2011; Hoggett et al., 2011; Chignell & Gross et al., 2012). Therefore, there is a question over whether the market structure currently in operation is able to provide for a low carbon future. This has been identified by a market-based stakeholder (interviewee 6), a government-based stakeholder (interviewee 21) and a regulatory based stakeholder (interviewee 19).

The different market, identified by interviewee 6, would be that it would support the small-scale generators rather than penalise them, as discussed by interviewee 21 and 19. Many of these changes have been identified by the Electricity Market Reform through the Contracts for Difference, however, this has been criticised as a way of subsidising nuclear power (Toke, 2011; Mitchell, 2011).

It is clear that the current market structure has been set up with the centralised approach in mind. This means that the reforms will need to go further to promote the small-scale generation rather than keep its current structure. These can be in the form of a separate market dedicated to small scale generation. However, as the quote from a regulatory based stakeholder (Interviewee 19) suggests, the reformations have not gone as far as they could:

"It's remarkable that the Energy Market Reform does very little to the energy market" Interviewee 19 RBS

As the interviewee subsequently pointed out, most of the changes to the market structure are simply an adaptation of the standing system. The EMR is not a reform of the electricity market – i.e. BETTA - itself but is simply the same market structure with minor adaptations outside the framework of market operation. The reasoning behind the adaptation of the energy system, rather than a radical change, can be explained in different ways. One aspect could be that the development of the market structure is designed to remove Government from direct association with the energy system, leaving them with a reduced responsibility for any short-term issues, which may occur. This means the energy system will be left as an open competitive market place.

9.3.4.1 Market Competition

As identified in section 4.1.6 DECC has signified that it intends to use competitive markets as its main strategy towards ensuring energy security. However, there is a question of how competitive the current markets are perceived to be. If Government is trying to provide a free market system then the discussion from a market-based stakeholder here disagrees.

> *"Some people think it's a free market. Well, actually, no it isn't, it never has been and politicians have played around with it to their hearts' content for years" Interviewee 10 MBS*

However, for a market-based stakeholder any changes to the market approach could mean uncertainty in their future, the impact of this has been discussed in section 8.1.1. Therefore, Government intervention can be considered positive for the low carbon future as it requires a change to the current approach, but at the same time negative for the present energy companies who dominate the electricity system.

The balance of competition over intervention was also identified by Ofgem in the EMR consultations; it signified that Ofgem would prefer the Government to keep an open competitive market with little or no Government intervention.

> *"…we see that under the FIT proposal there may be a greater role for Government (than at present) in determining the generation mix. However we would ask the Government to consider maintaining competition between generation technologies as far as possible, so that an efficient price discovery can match. We consider that the appropriate use of competitive mechanisms is likely to lead to the best outcome for consumers over the longer term, whether that be competition 'in the market' or competition 'for the market'" (Ofgem, 2011e).*

However, Government intervention in the market is a balancing act that is not easy to perform. One of the issues for Government playing a more direct role in the electricity markets is to balance the returns for investors and excessively adding to the end cost of electricity for the consumer. Without this delicate balance properly managed then the UK Government could be criticised from either the market players or the civil society actors. E.ON identify the risk on not providing enough returns for an investment:

> *None of [the EMR] mechanisms removes developments, construction and operational risks which are major factors associated with new nuclear, SCCS, wind and biomass projects. Political risk will also remain. Returns will need to be adequate to cover these. (E.ON, 2011)*

However, what E.ON neglects to identify here is that there is also a risk of over paying these projects which increases the price to the consumer. Although this was identified by the Association of Electricity Producers (AEP) in the same consultation:

> *We are mindful of the impact on consumers. In their interests, the Government must demonstrate that its chosen measures are the most cost effective in delivering carbon emissions with security of supply. (AEP, 2011)*

Having said this, choosing the most cost effective measures is not a simple task. This is mainly because many of the aspects relating to the electricity system are not quantifiable. Government currently quantifies many of the different aspects of the electricity system. However, putting a figure on the benefits of an individual having ownership or a 'stake' in the electricity system is not easy.

> *To consumers, who will ultimately pay for these initiatives, to fully appreciate the financial impact of the proposals the economic rationale and financial impact is clearly articulated and understood. (AEP, 2011)*

The AEP identify that consumers may not understand how the complex market and initiatives operate and therefore, understanding the impact of reducing carbon emissions and ensuring energy security will have on the consumer bills.

The complexity of the markets means the small-scale investor and generator is at a disadvantage in their level of understanding of the electricity system operation. This complexity comes from the transaction charges and a need to predict output in advance. Due to this the small-scale generator is unlikely to operate in the BETTA market system. The complexity found in BETTA is also apparent in the EMR. Therefore as identified by Centrica, Government intervention would be required, calling for a more simplified market alternative.

"Implementation of the EMR package would create a complex electricity market with a high degree of Government intervention […] a simpler, more market-based alternative should also be considered." (Centrica, 2011)

However, there are support mechanisms for small-scale generation. Mechanisms such as the FIT enable a bypass for the small-scale investor around the market complexities, providing a clear cut understanding of how much the technology will cost in relation to how much it generates, as shown by a market-based stakeholder:

"Decentralised energy requires much simpler mechanisms to support them compared to large scale centralised generation" Interviewee 15 MBS

The FIT provides the small investor with information of upfront capital costs, the on-going costs, and the price received for generating electricity. This means an investor, whether they are a large corporation or a single householder can calculate the costs and returns of investment with relative ease. However, some stakeholders did not see the Feed in Tariffs as a way of supporting the electricity system as discussed below by civil society, market-based stakeholders

"the small-scale developer is generally being encouraged by feed in tariffs, basically being paid an excessive amount which exceeds the value of what they are doing in order to encourage them to do it. […]. Government is prepared to pay out huge amounts of cash on solar at a local level, not because it's the right thing to do but because it wants to try to develop the supply chain." Interviewee 31 CSBS

"None of the renewables stuff works without the subsidy therefore the subsidy is driven by policy and that is not a market driver at all, indeed often it's working against the market." Interviewee 18 MBS

It is important to note that each of these research participants represent or support, large scale generation companies which would view the promotion of small scale generation as possibly damaging to their own current portfolio.

Although the initial conception of the FIT did support small-scale renewables over and above the wholesale price of electricity, the FIT works to set up supply chains for nascent technologies and as these technologies become established the returns are reduced as was seen in the current FIT in 2012 (Ofgem, 2012a). The result of this is that the nascent technology can have the ability to catch up with and operate alongside current market technologies. However the current market approach penalises the variable renewable generation. Therefore, in order for small-scale renewable generation to enter the market place, it would likely require either a change to current market approach or a separate market system for small-scale generation. An interesting point to make here is that Government are using the market as its main mechanism in delivering energy security. However, many of the research participants do not see the FIT as a part of the this mechanism, this includes two government based stakeholders.

> *"by introducing large scale fit and capacity mechanisms you are distorting the markets. As soon as you start distorting the market you are making things more expensive only time will tell on this." Interviewee 14 GBS*

> *"a lot of decentralised energy is going to be subsidised, a lot of it is going to be renewable. So there is potential for problems to come out from my point of view. You are essentially muddying the market, reducing the effectiveness of price signals" Interviewee 21 GBS*

Interviewee 14 here identifies the feed in tariffs and capacity mechanisms as a distortion to the market, furthering this with the perception that this might cause an increase in cost of electricity. However, this occurs at present with the nuclear industry; the Government is subsidising the use of nuclear power through the contracts for difference, thereby raising the price of electricity for consumers, which is also on a relatively established technology..

Interviewee 21 identifies the "muddying of the market through" renewable subsidies as an issue for the price signals. However, in order for greater efficiency in the electricity system, price signals would need to also operate for the consumer, at the present time there are very little short-term price signals for demand.

The issue with this viewpoint may be the lock-in to a centralised approach, which has become established. Government based stakeholders may believe that the current centralised approach is easier to govern and therefore fail to see the benefits of decentralised electricity in the market.

This shows the importance of the markets to the particular investment and in turn the future technology mix. Therefore, the future of the investment scene depends on the success of the EMR. Whether the reforms better promote a centralised, or a decentralised electricity future, they will go a long way to determining the future of the system.

> *"The Government has talked about this under the energy market reform so we are going to see a floor price underneath carbon, effectively that is a subsidy for nuclear power"*
> *Interviewee 25 MBS*

For the case of decentralisation, many of the interviewees see the future as very bleak, this is identified in the quote from a market-based stakeholder. The issue with the markets is that they can be considered a major factor in the governance of energy security. If the research participants view the markets as penalising or promoting decentralised electricity generation then this would need to be addressed for a low carbon future to be envisioned.

The impact of the markets in energy security is the markets dominance in ensuring energy security (Temperton, 2011; Gross et al., 2012). Therefore, how the Government sets out the market arrangements and any subsidiary mechanisms such as the FIT will dictate the future of the electricity system. This means, the Government needs to provide a clear and strong indication of how the future low carbon electricity system will look. This brings back the concept of any policy uncertainty having a negative impact on energy security. This idea of uncertainty also follows on in the next section.

9.3.5 Investors in a low carbon future

In order to find the investment and develop a new electricity system, the type of investor that would be targeted needs to be understood. The current large scale centralised electricity system utilises investment from large global investors. Whereas investment for smaller scale projects would be more likely to come from communities, businesses and individual householders. What each of these different types of investors are looking at is the risk and returns involved with a particular project.

> *there is a serious risk that this investment will not be available if investors do not have confidence in the UK electricity market arrangements.(AEP, 2010)*

Without the right market operations and incentives investment would be unlikely. This was identified by AEP in the Carbon price floor: support and certainty for low-carbon investment.

The EMR, discussed in section 2.2 according to Government has been designed to provide long-term assurances for investors. One of the methods in which this is achieved is by putting in place a carbon price floor incentivising low carbon investment and reducing investor uncertainty.

> *"As we go forward we'll have decentralised power. You'll have a greater mix of technology and therefore more advent of small technology players and greater distribution of the assets themselves, therefore less belongs to the very large companies" Interviewee 6 MBS*

> *"The potential benefit from the investment of the smaller scale decentralised generation is that you open up projects which are at a level where you don't necessarily need to be a gigantic investor to be able to contribute" Interviewee 27 CSBS*

> *"If you have lots of New players you have access to new sources of capital I guess that would mean there is a wider pool that you can tap into the project finance and if that is the case then perhaps that would help with the investment challenge. It really depends on who are these players and what is the success of these generators on the distribution network." Interviewee 5 GBS*

> *"the introduction of new players to the market, increasing competition, increasing the diversity of energy supply" Interviewee 1 GBS*

> *"those players coming into decentralised energy but you are also much more likely to get community type smaller local companies who think about doing it as a side business. That brings a whole load of extra capital" Interviewee 21 GBS*

The move to a decentralised electricity system would involve a larger number of smaller investors, increasing diversity and removing the proportion of assets owned by the larger energy companies as discussed by market, civil society and three government-based stakeholders.

The one category of stakeholders not represented in this collection of quotes is the regulatory-based stakeholder. This may be because of the nature of the regulated monopoly of the networks means that in a decentralised electricity system their investment structure would not change. The investment would still be achieved through regulation.

The advantage of increasing the numbers of investors in the generation of electricity introduces greater flexibility in investment opportunities. Current investment works in a large scale for each single project, meaning that once the investment is in place there is a reduced ability to change. This inherent irreversibility of investments leaves the system rigid in its pathway (Fielder 1996; Watson & Wright, 2010). Smaller scale generation provides an alternative for the traditional 'lumpy' investment patterns that accompanies a centralised system (Sambeek, 2000).

Although, a larger number of smaller investors provide an increase in flexibility from the smaller investor is not without its risks. Investment works on two sides. Firstly, they would look at the risk of the investment itself and then secondly, the credit of the investor. If the investment is seen possibly as risky, but the investor is seen as a having a high credit rating, then the investment may still be approved.

> *"a lot of the centralised or large scale low carbon generation are being delivered by large scale utilities and investors who have good credit rating and the ability to raise capital at reasonable cost[...]The ability of individuals, small business and communities to raise finance at a competitive rate with what could be raised by a major international utility is questionable because the risk profile is very different"*
> *Interviewee 31 CSBS*

> *"I guess a lot of this comes down to perceived risk. So if I'm a bank am I more worried about lending to E.ON or a collection of smaller companies [...] E.ON for example has got a triple A rated credit rating to borrow money. Are you likely to get that down at the company that's a tenth of the size of E.ON?"*
> *Interviewee 3 MBS*

However, if the investment is seen as high risk and the investor has a low credit rating then the project could come to a halt. This is identified by interviewee 31 (civil society) and 3 (market stakeholder).

The two interviewees identified above are from different stakeholder groups, however, they both either represent or have links with large scale centralised electricity generators. It could therefore be understood that they would perceive investment into a decentralised electricity system as a high risk to their companies.

An alternative point of view is identified in the quote below from the same market-based stakeholder as above identifies the positives found in terms of the smaller investors being able to borrow money. These include the ability to find additional capital which in a centralised system could be deemed as inaccessible, bringing new types of investors into the system, as well as new, smaller scale generating plant.

> *"the communities own capital reserves, which they are willing to lend to the project at a much lower return because they've got a stake in it, and an interest in it. You do sometimes see that, where people will invest in things as a local community rather than looking for a commercial rate of return. So you can see an advantage of that model if it allows you to access capital." Interviewee 3 MBS*

Interviewee 3 here still identifies the investment as likely to have a reduced rate of return and therefore higher risk, they also identify a key aspect of decentralised electricity generation, that it has a number of non-quantifiable aspects which will need to be understood or at least taken into account. They identify that an investor may be willing to take on higher risk if they have a direct stake in the outcome of the investment. An additional point to make surrounds the way in which the banks in the UK can deliver to the small investor.

> *The banking system in Germany grew up with the smaller system and has found ways of meeting that demand. In the UK the banks have not embedded the knowledge and expertise into the small scale Interviewee 28 CSBS*

This identifies how changes will be required not only to the UK electricity system but also the other interlinked systems such as the banks in order to develop and promote a low carbon electricity system.

For the case of the nuclear power industry the financing of a project can often be made from a number of different investors. For example the proposed Hinkley Point C nuclear power plant is part owned between EDF Group (45-50%) and letters of intent from China National Nuclear Corporation (CNNC) and China General Nuclear Corporation (CGN) to take 30-40% between them, while reactor designer Areva will take 10% (Chazan et al., 2013).

With a centralised investment strategy you are trying to find large amounts of capital, as can be seen from the Hinkley C example they can often be from overseas (Sambeek, 2000). Where this investment comes from is important because the level and continuation of this investment needs to be secure.

> *"What you have got to do to get that investment is convince somebody to put it into UK generation, […] but you are also competing at the big level, whether it should be invested in a*

> *shopping mall in Hong Kong or Manila or whether it should be invested in mining in South Africa. Whereas if you go for decentralisation you move away from these people, the big banks, the Morgan Chase. And you move to smaller community groups Interviewee 6 MBS*

> *"Most of the people who are investing in assets and energy infrastructure are not indigenous UK businesses .The UK at the moment, whilst an open liberal market with plenty of investment, does not necessarily stack up strongly when compared to other options for investors to invest." Interviewee 31 CSBS*

This type of investment means competition at an international level as identified in the quotes from market and civil society based stakeholders. This could mean a higher risk to large scale generation for the electricity system. Interestingly, risk is often discussed in terms of the policies, rules and regulations being set out to reduce risk for the investor. However, with only a small number of main players (such as a centralised system) and the risk involved can be discussed in terms of the requirement on the players in investing in the electricity system. In addition to this the scale of the centralised generating stations such as nuclear means they are too large to fail, as discussed by interviewee 8 (GBS).Thereby creating more risk of additional costs to the electricity system.

One of the main features of a decentralised electricity system is that it includes a larger number of smaller actors and stakeholders. By utilising a larger level of decentralised generation an additional investment portfolio is introduced. As discussed in the quote below from a civil society based stakeholder, the idea of finding the investment is beyond the 'capacity of current utility structures'.

> *"you start getting different non energy actors entering the energy field, this is where we talked about the need to have massive financial injections that is beyond the capacity of the current utility structures.?" Interviewee 4 CSBS*

This point is one of the main features decentralisation can bring to the electricity system. It goes back to the discussion that economic modelling which currently dominates many of the future energy scenarios from Government, may not feature this benefit in finding investment for a low carbon future.

9.4 Summary

This chapter has looked at the investment issues and proposals for the future of the networks and generation. It has identified the research participants' perceptions for the future of investment in a low carbon system. It has also discussed how decentralised electricity would likely bring a different avenue for investment through its scale and ability to be implemented in a short timescale when compared to centralised generation. A decentralised electricity system would also likely develop the way the network operates.

One of the main impacts of a decentralised electricity system is on the distribution network. This will include adjusting the DNO's link to the transmission network and alter the demand profile. As the level of decentralised electricity generation grows the distribution networks will have to change alongside. The research participants did not show concern that the networks could not cope technologically with an increase in decentralised generation as long this happened over a long enough time scale. They saw no problem in the networks and network operators developing at the same rate as the rest of the electricity system.

However, the changes brought by a decentralised system for distribution network would require an increased level activity on behalf of the DNO's. The question here was whether the DNOs would be willing to take on that risk and put the investment in place. Once again the answer came down to one of cost, as long as the operators were sufficiently compensated for the increase in risk then they would be willing to invest.

Therefore, the electricity networks may require substantial upgrade and investment in order for them to fulfil their future role. How this investment is to be attained, was discussed by the research participants in this study. It was identified that because of their monopolistic nature, investment in the networks are regulated and therefore with the right regulatory framework the investment should be achievable. However, this was also seen as hindrance by some of the participants.

The promotion of greater investment in the electricity system can be characterised in two ways: by an incentive or a penalty. Incentives are made by making the generation technology cheaper to produce or more profitable during its lifespan. Penalties can be formed by the act of not moving to a low carbon system, such as over running the EU ETS allowances (Carbon Trust, 2008). This was discussed by one of the interviewees (interviewee 31, an energy consultant). The discussion involved how and who determines the penalty for not meeting the UK Government targets.

If the penalty is too low then it could be seen as cheaper not to meet the target. For instance, if it costs £70.5bn to meet the Government's low carbon goals for investment into generation (as identified in Ofgem's Project Discovery) and the effect of not meeting its low carbon goal is much less than this, then there is no incentive to invest. However, in general, the cost of reducing carbon emissions will get higher the longer it is left (Stern, 2006). This falls back to Government direction and whether they send clear signals to the investors on the direction the energy system will take.

The cost of moving to a system with an active operation for the DNO's was another important point. The consumer is already paying additional charges for carbon reduction policies, on top of this would be the costs of developing an active system. The main discussion here is, would the cost of introducing an active and smart electricity system outweigh the benefits. These benefits include energy efficiency improvements which reduce costs for the consumer, the level of generation required and the positive impact on climate change targets. In addition to this, if the networks can be balanced in their local area then additional infrastructure further up the line might not be required.

However, the move to a decentralised electricity system would require substantial back up from the transmission system. Therefore, even though a decentralised electricity system may be able to avoid investment to renew the transmission system you would still need to find a way of paying for its use as back up. Further to this the transmission network owner will likely need compensating for the reduction of 'traffic' on its network by developing a suitable reward structure.

Investment in generation is a far more complex issue, it includes factors such as the risk involved with a specific generation technology, the profits found through the wholesale markets and market mechanisms and the type of investors who are involved.

One of the biggest concerns with the future security of the energy system is the impact of the European directives (LCPD and IED) which will result in a substantial level of UK capacity being be lost. There was a discussion over whether the UK Government would find a derogation on these directives. However, the evidence to suggest this would not happen is strong. This may be an indication that the market players either have very little trust in Government, or the security concern for future capacity is so high that the power plants will have to continue.

Therefore, replacement generation would need to be built. The first wave of closures are due in 2016 and the impact of which has already been felt (see section 2.5.1). The options for replacing this generation are limited as the time scales are so short. If this capacity is to be replaced with low carbon generation, then in the short-term at least, nuclear power is not an option, leaving renewables as the most likely opportunity. An alternative option is to use gas-fired generation as a transition technology and hope that carbon capture and storage technologies will be operational in a short time period. The advantages of gas generation are its quick build times and flexibility, making it suitable as a source of backup capacity.

Combined cycle gas fired turbines would provide a good back up to low carbon technology especially during the transition to a decentralised system. However, the capital needed to invest in a gas fired generation plant would mean that this technology needs a solid foot hold in the future electricity system. As back up this technology has an unsure future. A policy discussion, which assures its future in the market is needed in order to make the investment worthwhile.

The wholesale market has been designed as a competitive system and is often looked at as the main mechanism for delivering electricity security of supply. This competitive feature of the market was seen by some as an issue when six energy companies dominated the market. The move to a decentralised electricity system would introduce a much larger number of companies to the electricity system. This would introduce a greater number of stakeholders to the electricity system, increase the diversity of investors and opens up competition in the supply of technology and, with the right mechanisms and structure, the market. However, in a decentralised electricity system the type of investors would also need the knowledge and understand of these market operations and supply chains, which might be extremely complex if they are based on the currently used models.

This section has discussed the difficulties in finding the right investment to ensure a secure energy system and the changes which moving to a decentralised electricity system may bring to investment. However, energy security is far more complex than simply supplying electricity. An on-going theme within this chapter was the level of clarity and trust the stakeholders have with Government. The lack of understanding and belief in the future of the electricity system may undermine the investments to be made. This may be a function of the level of responsibility UK Government has over the electricity system. The next section will look at who is responsible for ensuring these additional aspects of energy security looking at the electricity system as a whole.

10 Responsibility for Ensuring Security of The UK Electricity System

The previous section looked at the stakeholder's perception of investment in the networks and generation for a low carbon future. It discussed the impacts a decentralised electricity system may have on investment. Specifically the ability for decentralised electricity generation to open up new avenues for future investment. The small-scale investment associated with decentralisation allows the introduction of investors who would not have existed in a centralised system.

During the process of the primary research for this thesis, two significant questions arose. Firstly, who is currently responsible for energy security? Is it a single organisation or the combined actions of a network of stakeholders? Secondly, what are the possible challenges or changes a decentralised electricity system would bring to this situation? The impact of these questions directly links to the governance of the electricity system. Through, the relationships of the actors which form the governance and therefore the perception of responsibility will help describe the actor relationships. Thereby, directly adding to the discussion of governance for energy security.

In order to answer these questions, this section will use the statements given by the research participants regarding roles and responsibilities for energy security to develop an understanding of the changes an increase in the number of stakeholders may bring. This includes a change in the number of power plants, their owners and the investors (see section 5.1). In order to do this a definition of responsibility is first required.

Responsibility as discussed in section 6.3.2 can be defined from an ex-ante or an ex-post viewpoint. An individual or organisation can be deemed liable for an event through the choices they have made, making them accountable for their actions. Or it can be viewed in terms of individuals or organisations conducting themselves in a manner, which either promotes or supports an issue, whether through a moral sense of duty or obligation (Umbach, 2010).

This thesis discusses the changes in governance that a move to a more decentralised electricity system may entail, as an increase in the number of stakeholders involved will change the dynamic of the system. Exactly what this means in terms of responsibility is not, at present, clear, because the term ‘responsibility’ is ambiguous and a multi-layered concept (Giddens, 1999; Gunder and Hillier, 2007). The complexity of the concept provides a range of plausible definitions, which can be specific to the context in which they are used (Bovens, 1998). The definition used in this thesis will obviously be based in the policy context. However, in the policy context, the idea of responsibility is often discussed but rarely defined (Pellizzoni, 2004). In the context of liability, responsibility is based on the premise that your actions are voluntary and performed within the full knowledge of the situation (Wallington and Lawrence, 2008). Therefore, in order to make a particular organisation responsible for its actions, the State is required to clearly define its aims and apply rules and incentives to achieve this (Pellizzoni, 2005).

For the purpose of this research, responsibility will be considered to apply to an actor, or group of actors, who have the ability and obligation to act. This means that the level of power an actor holds can have an impact on their responsibility (i.e. low power, low responsibility and vice versa) (see section 6.3.2).

This chapter will identify how the research participants view the responsibility for energy security. It will begin with the perception that it is Government’s responsibility for the system security. Energy security is secured in different ways by different countries (Soutar and Whiting, 2013). Some countries (i.e. Denmark) hold a single organisation accountable for overseeing the security of the entire energy system. Other countries such as the UK do not. However, the UK Government does have a legal responsibility for energy security set out in the Electricity Act (1989). The reality is that Government is responsible for supply security, not the broader definition of energy security.

This chapter will pursue the hypothesis that energy security as identified in this thesis is, and needs to be, the responsibility of a network of actors and stakeholders in order to ensure a long-term low carbon, secure future.

In addition to this the impact of the perception that energy security is the responsibility of the Government means that the stakeholders have given the power to Government in deciding the future of the electricity system. The result is that Government can be considered to be focussed on delivering security through centralised electricity technologies thereby obstructing decentralised electricity’s role in energy security.

The UK energy system security is maintained through a wide range of stakeholders and energy system actors. The central actors include, Government, the Regulator, the Network Operators and the Energy Companies. **Error! Reference source not found.** below identifies the roles of each of these actor groups.

- **Government**
  - **Set policy framework for decarbonisation**
    - **Investment in low carbon technology via the EMR**
    - **Capacity via the EMR**
  - **Set the Duties and give guidance to the Regulator**
    - **Networks transmission and distribution**
    - **Market**
    - **System Operator**
    - **Retail Competition, i.e. liquidity**
- **Regulator**
  - **Ensuring appropriate regulation for**
    - **Transmission operator**
    - **Distribution operator**
    - **System operator**
    - **All Costs and Licences**
- **Network Operators**
  - **Ensuring the Network is operational**
- **System Operator**
  - **Balancing of the Network**
- **Big Six Energy Companies**
  - **The changing technical issues**

Figure 10-1 Roles of each actor group

It is clear that a low carbon future will change the roles and responsibilities of the stakeholders in the energy system. This has been recognised by DECC in the Smart Grid Vision and Routemap:

> *we need to rethink the roles and responsibilities of all the players in the electricity system (DECC and Ofgem, 2014: pg. 6)*

In the UK there is an interrelated set of mechanisms and incentives to ensure the various dimensions of energy security are controlled. Responsibility of each of these dimensions can be associated with a particular stakeholder or group of stakeholders operating within the electricity system. An example of this would be the electricity network operators who have a responsibility to ensure the networks are operational for the delivery of generation.

10.1 Government responsibility in the energy system

As discussed in chapter 6 the governance of the energy system can be analysed in many different ways. When viewed as a hierarchal structure the Government and by extension, the Department of Energy and Climate Change could be considered as being at the pinnacle for the electricity system (Rhodes, 2007; Rotmans & Loorbach, 2008; Pahl-Wostl, 2009). However, modern governance theories have identified a multi-faceted approach to governance illuminating how a single group, in practice, does not hold all the power. Whether the theory coincides with the reality is another question.

DECC have developed four priorities over the last few years: the support of vulnerable consumers; the delivery of secure energy on the way to a low carbon future, driving action on climate change, and managing the energy legacy delivering value for money (DECC, 2012d). In order to achieve these goals, different mechanisms and operational structures are being established, such as the reformation of the electricity market, which is intended to provide a low carbon, secure future (DECC, 2011a).

Equally the New Green Deal is intended to help reduce energy consumption for the householder, business and public sector. These mechanisms and policies could be considered to define the future of the socio-technical regime and in turn dictate the actions of the electricity system actors (Verbong and Geels, 2012). Therefore the significance the Government gives to each of these challenges can define how the energy system develops and in turn whether they have a significant impact on energy security or not.

This section will look at the stakeholder perceptions of Government. It will identify what the stakeholders believe the current responsibilities of the Government are and then establish how this could change in a system of high levels of decentralised electricity generation. It will begin with the historical and current viewpoints on the level of control Government has. It will then look at the perception of

Government towards a decentralised system and finally the Governmental priorities and motivations.

10.1.1 Government Control

The Government, from the 1980s to 2010, can be considered increasingly disengaged from the energy system (Helm, 2002; Umbach, 2010, Chester, 2010). The liberalisation of the energy system removed Government from directly owning any assets associated with the electricity industry (Stern, 2010). Therefore their ability to have a direct impact on the energy system altered from State owned monopoly days. Nevertheless, the policies and mechanisms they implement have the potential to orientate the energy system through markets and the promotion of certain investment avenues. It could be argued that the EMR has identified a shift in Government to become more engaged in playing an active role in the system. The EMR, as discussed in section 2.2, can be considered a positive promotion by Government to develop a strategy promoting energy security. This is clear through the capacity mechanism where the Government's aim is to stimulate sufficient investment into electricity generation capacity to meet electricity demand at all times.

Government is also responsible for setting the duties of Ofgem, the regulator. Ofgem can then cascade the technical and regulatory requirements to system actors through the codes and licences and incentives. Government is therefore ultimately responsible for ensuring that the rules and incentives with the electricity do promote energy security.

Given that Government directs the electricity system including investment and operation through its policies or via duties on Ofgem for regulation. Is Government in reality the main stakeholder involved with delivering energy security? As identified in the section 4.1, Government prioritises short-term security of supply and it would be the responsibilities of the system actors to ensure long-term security.

However, there is a question over whether stakeholders, such as the energy suppliers are best placed to deliver Government policies.

> *"Government, I don't think, feels confident at going out to the consumers and telling them the story of the scale of the additional cost. We get a very obscured way of expressing it from Government. The utilities, when I talk to them, feel that*

anything that they try to say to explain to the consumer that bills need to rise is perceived to be a self serving justification for driving profits up." Interviewee 31 CSBS

"In the old days, CEGB, national grid, everything was decided in Whitehall and they were just told to get on with it. So price changes were politically decided. Then they nationalised it all and you've then got the Big Six. The Government don't treat it as an arm of state, through all the initiatives, warm homes, and FIT to a certain extent. We need a policy on energy security, let's get the energy companies to deliver in a way that they wouldn't tackle food security via control of the supermarkets." Interviewee 6 MBS

As identified in the previous chapter, (section 9.3.1) there is a requirement for Government to be clear about its future vision for the electricity system. Any uncertainty would be detrimental to energy security by making investment more risky. This is also shown in the quotes above from interviewee 31 and 6, where the research participants identify that they are constrained by the Government policies. The energy companies have a direct link to the consumers, making them the main link between the consumer and the energy industry. However, from a business point of view the suppliers are trying to maximise their sales and therefore providing energy efficiency technologies would seem counterintuitive unless they can make more money selling services that they can supply. This is explained in the quotes from a market-based stakeholder and a civil society based stakeholder.

The point to make here is that because Government does not own any assets in the electricity industry, they have to rely on other stakeholders to deliver their policies. They rely on the network operators to maintain the distribution and transmission network, on the System Operator to ensure the balancing of the network, and on the energy generator to deliver investment into new capacity.

Therefore, Government does not have complete control to ensure the security of the electricity system. It does have the ability to develop the framework which can influence a future of energy security.

The concern from the research participants above is that these policies should not be operated through the energy companies. Government should shoulder the responsibility and ensure security themselves.

Having said this, the British market approach to energy security has, so far, provided sufficient generation capacity. One regulatory based stakeholder noted the future of the energy system is “unclear” (interviewee 19). Whilst the importance of the LCPD and IED are largely understood – reducing amounts of high polluting coal plants- it is unclear which technological replacements will be favoured. Whether nuclear, renewable, or fossil fuels with carbon capture technologies or a mixture of these. Additional uncertainty is caused by the need for investment in peaking capacity in a system with high levels of variable power. Therefore, the future of the electricity system requires strong Governmental direction (Parag & Darby, 2009).

> *“The risks and the dangers are actually down the booms and bust cycle the Government put us in. They ramped everything up for FIT and then they are doing to ramp it down again because there is a shortage of Government money. They have done that before with the grants.” Interviewee 6 MBS*

> *“There is a requirement to have a greater mix of decentralised energy in our system which I am pretty sure is the industry consensus. And the trend is going in that direction. But despite that there is no coherent Government strategy to work out and define what that role is and say ‘this is how we are going to do it’. I would say from a control point of view you are loosening administrative control. But on the other hand you are providing a lower risk incentive through the feed in tariff to encourage generation … ” Interviewee 15 MBS*

Without strong Governmental direction, investors looking at a specific technology may not feel confident about the future and therefore not provide the investment required (Laing & Grubb, 2010; Gross et al., 2010).

The discussion here regarding industry consensus is likely to depend on which actor is making the argument. As discussed earlier, the main mechanism Government uses to ensure a secure system can be considered to be the markets and the market mechanisms with Government intervention when required. This addition of Government intervention in the ESS (DECC, 2012o) is interesting as it does not suggest how much intervention and it does not set out when it may be required. However, the move to greater decentralised electricity would change this.

> *“So if you work on the basis that financial instruments for smaller companies are being used, this transfers the risk from the generator towards Government.” Interviewee 15 MBS*

As identified by interviewee 15 the general consensus between the research participants was that the role of Government in a decentralised electricity system could change. This level of change would depend on how the decentralised electricity generation is incentivised (i.e. through a separate market or utilising a mechanism controlled by Government such as the FIT) then it is likely that the Government's level of responsibility will increase.

Government would therefore be directly responsible for setting out the type of technology required for the future electricity system. This would indicate a very dictatorial role for Government, thereby increasing their obligation towards energy security.

Another option, is, a separate market specifically for the small-scale generation is established. This would then release Government from additional responsibility for the energy system once the market has been established.

A further point to make for a decentralised electricity future is whether any obligations placed on a larger number of smaller suppliers would reduce the individual companies' responsibility and lead to an increased level of responsibility for the Government. However, there is very little to suggest that a change from a small number of larger energy companies to a larger number of smaller energy companies would change the risk and perceived level responsibility of Government.

If this were to be the case, the Government vision of the future electricity system becomes increasingly important. Whether Government would prefer to decarbonise the current centralised energy system or whether a highly decentralised electricity system would better suit their requirements for governance. In 2007 the then Secretary of State for Trade and Industry, Alistair Darling commented on the idea of Government influence over the energy system actors (New Statesman, 2007). He stated that it would be far easier to make a change to six large energy companies rather than attempt to influence every individual householder. Although this is a statement made by the previous Government, the message may still ring true today, it is also echoed by Interviewee 3, a market based stakeholder.

> *"…if I want to achieve change in behaviour on the part of every household in this country, it is easier to persuade a small*

number of providers to bring that process about than it is for millions of individuals." (New Statesman, 2007)

"The Government would find it easier to negotiate with 6 large utilities rather than a 1000 smaller ones." Interviewee 3 MBS

One explanation for this could be the links that Government has with industry. With a smaller number of energy companies involved, Government-Industry communication would be easier than with thousands of companies.

The problem with this is that it disregards many of the benefits of involving the individual householder with the energy system. This can include, the operational processes of the energy system in terms of demand response and by the inclusion of the individual householder in providing an additional source of funding for small-scale generation. However, the research showed that Alistair Darling was not alone in supporting the idea of only having to deal with a small number of stakeholders, the quote below from one of the market-based stakeholders shows how negotiation must be a major factor in Government's role in the energy system.

"If I was sat in Government I might be concerned that I was losing my grip on the energy industry. The way everything is going at the moment is that it's being centrally controlled. And when push comes to shove the energy minister can call the heads of the big six into his office and say look there's an issue here, how are we going to sort it? I want you to do this 'XY&Z.'" Interviewee 3 MBS

The centralised control of the electricity system discussed in the quote above is in the context of long-term planning for a balanced grid over the whole network. What the participant identifies is, the Government wants to have close control over the operational aspects of the energy system. The suggestion here is that a decentralised electricity system would mean that the nature of the dialogue between the Government and the energy companies would change, moving away from the intimate relationship currently held. However a counter argument was made by interviewee 4.

"The way in which current large generators influence regulation and energy legislation would be very different if the ownership were with a larger number of smaller companies." Interviewee 4 CSBS

From a technical perspective many of the problems that can be caused by using large scale generation plants would not have the same impact as a large number of small-scaled installations. For example the timing of routine maintenance of a large scale plant would have a larger impact on a particular area of network compared to the maintenance of smaller scale generation.

A decentralised electricity system would likely mean a reduced amount of power to any single energy company. Therefore, reducing the influence of industry in lobbying, for the benefit of energy companies over energy goals.

One strategy the Government has regained control in the electricity system is the implementation of the EMR. Although along with this control comes a great deal of responsibility and therefore political risk.

In 2011 the Government published a White Paper (DECC, 2011a), setting out the Government's plans to reform the electricity market so that it is more able to deliver energy policy goals. Electricity Market Reform has been discussed in more detail in section 2.2, where the key policy mechanisms (CfDs and the Capacity Market) were identified and discussed as drivers for investment in either low carbon or flexible generation plant.

> *"The EMR is very quiet on decentralised energy. It makes limited reference to demand side measures. When it appears to be a principally a mechanism to try to stimulate mass investment in zero carbon assets and there's quite a strong perception it thinks that it's trying to stimulate new nuclear, which by its nature won't be decentralised energy." Interviewee 27 CSBS*

> *"The Government policy says we want low carbon, we want efficient networks, and yet the rule book and the charges all make it harder and harder for small-scale developer to actually deliver that." Interviewee 12 CSBS*

The emphasis in the EMR documentation is largely focused on centralised generation, and there is little attention given to issues around decentralisation. However, it does acknowledge decentralisation's ability to deliver solutions which meet the demand of local people and communities and also provide new opportunities for local business, although it lacks any real detail in how decentralised electricity will be promoted. The comment here from interviewee 12 identifies the importance of Governance in the development of the electricity system. The research participant is discussing the rules and incentives, which allow a small-scale developer to sell its electricity on the wholesale markets. These are the licence conditions, which place rules on how the stakeholders can operate.

Therefore, the rules and incentives necessary to form a decentralised electricity system will need to be accessible to the small-scale developer. If they are too complicated they will limit the type of investor able to promote this type of system.

Interviewee 3 indicated that in order for this to work the rules and incentives of the operational processes would need to be adapted.

> *"You'd have to legislate and say that decentralisation has got to provide the services that are currently picked up by the large generators through their licence conditions, because you are no longer getting that balancing done at the grid level."*
> *Interviewee 3 MBS*

Interviewee 3, from one of the larger market-based stakeholders is correct in the current market approach. However, a decentralised electricity system would need a market that supports small-scale energy

10.1.2 Government Priorities and motivations

The UK Government has established a set of factors, which energy policies and mechanisms need to address. These include energy security, fuel poverty and reducing carbon emissions. Understanding which of these factors is most important to the UK Government could be considered unanswerable as it is likely to be a fluid, changing result which would be dependant on a number of factors(Bang, 2010). The concern over each factor individually is related to many different aspects, such as pressure from the general public, industry, or international agencies. It is the Government's role first and foremost to ensure the protection of the UK citizens. However, as each Government is put into power through the voting of the general public how this protection is be achieved can be swayed. If the general public showed a strong need for action in a particular area then Government would be inclined to follow this lead (Hughes, 2009; Bang, 2010). One example of this is discussed in section 9.3, there was a question regarding the closure of many coal-fired power plants because of the LCPD and the IED (see section 2.5.1). The interviewees identified that the LCPD and IED may pose a threat to energy security. This threat may mean that the directives would not be followed through as energy security is of a higher importance to consumers. However, as discussed in section 9.3.1, ignoring the directive would be unlikely because they are set in law. In addition to this many of the coal fired power stations have begun to close with the understanding that they will no longer be able to run when the directive is in place.

In 2010 the then Secretary of State for Energy and Climate Change Chris Huhne referred to energy security as being considered up until recently a "second order issue" (DECC, 2010c). This implied that energy security was moving closer to the forefront of Government agenda. In the light of recent high levels of energy security (DECC and Ofgem, 2013), it would signify a possible concern for the future security of the energy system. Another motivation could be due to a change in Government's concept of energy security as discussed in section 4.1, moving from a notion of primary supply security to a more complex idea involving the sustainability of the operation and the overall cost of energy (DECC, 2012o). However, with the recent economic crisis, affordability of electricity and heating has become a much more prominent political concern (Umbach, 2010; Schauer, 2009; IEA, 2009).

> *"Affordability has come right back up and if anything is sitting now on top of the agenda. Three years ago it was probably environmental issues. Then sustainability, I think we are now beginning to see security of supply rapidly moving back up the agenda." Interviewee 31 CSBS*
>
> *"I actually think that there isn't a real risk of the lights going out. It is, can we ensure that we can keep the lights on at a reasonable cost? […] I can't see in our economy with our politicians and in our industry will let that happen, barring some earth shattering event, some awful war or something unforeseen." Interviewee 12 CSBS*
>
> *"What is the Government's priority over the three main goals of energy policy? Energy Security, Climate Change, Fuel Poverty. In countries such as Finland fuel poverty is not seen as an issue at all. This is not through cheap electricity or better housing stock it is simply a matter of a good welfare system" Interviewee 10 MBS*

The link between affordability and security has been discussed in chapter 4. Vulnerability to fluctuations in energy costs, whether caused by the level of available resources or the costs incurred in generation is a sign of insecurity. This notion is echoed in the quotes from civil society stakeholders. These shows an increase in concern for energy security from a perspective of affordability and its impact on the economy. The reason for this is that the cost of electricity is a short-term indicator for energy security. There is a link between the short-term availability of supply with the end cost to consumers. Therefore, it is understandable that the civil society-based stakeholders would want it as a priority of government policy.

The third quote from interviewee 10 here identifies an interesting point. It shows the interrelated links between different Government goals. Therefore, if a state has a low level of national poverty, then overall affordability of electricity is unlikely to be a dominant concern.

It is clear that the UK Government is perceived by the research participants to be a principal stakeholder responsible for energy security. This thesis argues that Government is focussed on security of supply and not on the broader concept of energy security. Without a broader outlook for energy security, Government has centred many of their policies and mechanisms for security on centralised electricity technologies. This is evident through the EMR (see section 2.2) and in the ESS.

This thesis suggests that in order for energy security to be achieved it cannot be organised through a single stakeholder. It has to be the responsibility of a network of actors working together. This chapter will now explore the roles and responsibilities of these other key stakeholders.

10.2 Role of Ofgem

The role and responsibilities of Ofgem have been set out in the legislative framework organised by DECC. The primary role of Ofgem is to protect the consumers through the promotion of competition and the regulation of the networks that monopolise the system (Utilities Act, 2000). Additional priorities include *"helping to secure Britain's energy supplies by promoting competitive gas and electricity markets - and regulating them so that there is adequate investment in the networks"* (Ofgem, 2012c). This identifies that Ofgem has a priority towards ensuring the markets deliver electricity to meet demand. Thereby signifying Ofgem's role in security of supply and identifying them to have a role in the governance of the security of the electricity system.

Therefore, it would be fair to suggest that Ofgem could be considered to have a relatively high level of responsibility towards energy security. However, when asked, the participants rarely identified Ofgem as having a role in energy security.

Their role is discussed as simply to ensure the Government's framework is in place, as identified by interviewee 14.

> *"I think Government would sometimes like to think that it is not responsible, but I think Government is responsible for setting the right framework and policy. The energy regulator will have to make sure that policy is implemented and complied with" Interviewee 14*

This lack of discussion from the research participants of Ofgem's role could be for a through the way in which energy security has been perceived; often the view is that security of supply, which means the responsibility may be with the organisations that have a direct association with electricity generation and delivery.

Having said this interviewee 5 did provide a good statement identifying the different stakeholder responsibilities.

> *Short term operational security it is national grid. At a slightly more nebulas level it is the market and Ofgem as the regulator has a duty. Then at a political level the energy minister. Interviewee 5 GBS*

It is the Government's role to set the guidance and duties on Ofgem who then have a responsibility to execute them. An issue with this is that the legislation set can be considered broad, and requires Ofgem to interpret their duties. The reason for the open and general legislation is that Government does not wish be seen to micro-manage an independent regulator. This implies that Ofgem's responsibility for energy security could be based on how they interpret the broad set of duties placed upon them.

In a system of decentralised electricity generation Ofgem's role could be different. The current electricity system sees that a small number of players would operate and own the majority of electricity generation and supply. It could be argued that an increase in the number of organisations and stakeholders would provide greater diversity within the market (as long as a market approach is utilised). Thus the level of competition would increase. This increase would be in the number of electricity generators each with different technologies and levels of skills. The operational structure of the decentralisation would be different including changes to market mechanisms and the regulation of the networks to promote small-scale connection. Ofgem would then have to adapt in order to meet these changes.

However, even though a decentralised electricity system will bring many changes to the governance of the electricity system, the primary role of Ofgem is unlikely to change. Although Ofgem has a legislative responsibility towards delivering security, the governance of the electricity system is still set out by a network of stakeholders who are attempting to achieve a common goal, that of a secure low carbon future. The role of Ofgem is to aid in the delivery of these goals whether they should be a through centralised or decentralised process.

10.3 Role of Network Owners

Often considered to be in the frontline of short-term security of supply are the network companies, specifically The National Grid Transmission Company (NGTC). The NGTC can be divided between the transmission operator arm and its system operator function (an entirely separate division of NGTC) who's influence will be discussed in the next section.

> *"I think distributers are very much, as opposed to transmission companies and generators, second order you could even say tertiary in terms significance to security itself. "Interviewee 3 MBS*

> *"a distribution company, to give a bit more perspective is obviously not so engaged in energy security as perhaps a supplier or a generator might be." Interviewee 23 RBS*

Currently, the role of distribution network operators (DNOs) in system wide security is limited. At present, they do not have the ability to impact on the short-term supply of the electricity profile, other than ensuring their network is operational. This was indicated by most of the stakeholders interviewed and shown in the quotes from interviewees 3 and 23.

Interviewee 23, a representative from a regulatory-based stakeholder (a DNO) is discussing the balancing of the network rather than the impacts of energy security as a long-term and short-term issue of the electricity networks. Therefore, although the DNO's have a responsibility to ensure the networks are operational, interviewees seem to consider them to have a low responsibility for energy security. This may be because the concept of security is often understood in terms of supply meeting demand. However, energy security is far more complex, In addition the network operators are responsible for the ability of the centralised generation to access the grid. They are also responsible for additional costs of generation caused from short-term outages, by failure in the power lines or natural disasters such as trees coming down on power lines of floods. Also short-term outages could be caused by failures in the power lines or natural disasters such as trees coming down on the lines or floods.

However, a counter argument by a regulatory based stakeholder group (CE electric) showed that this may not the case for all distribution network owners. In the consultation for the EMR, CE Electric identified that its participation in the electricity industry means it has a role in ensuring energy security:

> *Although CE does not have investment in electricity generation assets, it considers that it has a relevant contribution to make to this consultation on two grounds. CE has a clear interest as a significant participant in the electricity industry in helping to ensure that the electricity market provides adequate incentives for generation capacity, but since it has no investment in generation it can bring a knowledgeable but impartial perspective to solving this problem. (CE Electric, 2010)*

This is a clear indication of the reality of energy governance. CE Electric show they have a role and a responsibility towards energy security even though they have no generation assets and very little power to ensure energy security at present. Having said this, the future role of the DNO will involve an increase in activity on their network. This arises from extra generation connections and a possible increase in operation and responsibilities including the balancing of the local networks.

One of the main impacts on the future of energy security is that in order to handle a large amount of generation on the distribution network, the operational system would have to change. At present there is a single System Operator who balances the whole network through the transmission system.

> *"You are dealing with small numbers. If something goes wrong, national grid can ring the power station up and sort it out, whatever, and it's translating that down to now having a system with thousands and hundreds of thousands of providers of these services." Interviewee 3 MBS*

One option is to have this SO take on the task of balancing all the different networks. Another is to make the DNO balance their individual networks. This would mean that it would be responsible for ensuring local grid security. This scenario may also require the overall SO to balance between the DNOs adding further complexity in the balancing of the whole system for System Operator. This was identified by a market-based stakeholder.

However, this also works in the opposite direction, with smaller numbers of large generating plants each one can have a greater impact on the electricity balancing. If a single generation plant shuts down then it can be more difficult to balance the network in that area. In a decentralised electricity system if a generator has problems the impact is minimal in comparison as other stations can fill the shortfall. It is clear that the network owners at present have a minimal role in energy security other than ensuring the running of their networks. However, it is also clear that the future role of the network operators whether it is centralised or decentralised will be very different and involve them in security to a far greater level. Therefore, their aim now should be to identify how they can fulfil this future responsibility.

10.4 System Operator (SO)

The SO has a responsibility to provide short-term generating provision, which covers anomalies in demand prediction and technical failures in generation. The SO also has a licence obligation to ensure that sufficient capacity is available to meet demand (Energy Act, 2013). Therefore, the SO can be considered as essential to the front line security of supply.

Concern around the National Grid being able to meet its responsibilities as the profile moves to a more decentralised system was identified by some of the research participants. The discussion is from an operational point of view, suggesting that the move to greater numbers of smaller generators and generation companies the portfolio of generation would become far more complex.

> *"You progressively lose the firm handle on what likely generation profile might look like and where it physically is." Interviewee 31 CSBS*
>
> *"What we say at the control at the moment is people individually are erratic and unpredictable but as a group we have a pretty good idea of that they are going to do which is why we have a pretty good degree of accuracy. We have a good forecasting and it would mean we would have to extend that forecasting capability to a much wider range of activities across the whole of the day." Interviewee 17 RBS*

Currently, the small-scale generation technologies are considered as negative demand. The network does not have any information of generation in a specific area and as the local demand consumes the generation before it reaches the transmission network no information is returned to the system operator. However, as a decentralised generation profile increases, the system operator will require greater levels of information to balance the network. This is shown in the quote from interviewees 31 and 17.

However, there is no reason to suggest that the development of the electricity networks would not coincide with the move to a decentralised electricity system. This issue was also discussed by one of the regulatory-based stakeholders, the increase in small-scale generation was not considered a major concern. The growth of the decentralised electricity generation will coincide with an increase in information transfer over the networks. Therefore, as long as this expansion of small-scale generation is not achieved too rapidly, then the balancing of highly decentralised electricity generation system would not be a major concern. This is shown in the quote of the regulatory based stakeholders:

> *"The bottom line is on system balancing. We need information, we need secure action channels to the people who can make a difference particularly at short notice very close to real time. So we need information and controls to do our residual balancing and system balancing roles."*
> *Interviewee 17 RBS*

The extra infrastructure which will be required to balance the grid, will also allow DNOs to reduce inefficiencies within the network as well as providing data for the consumers which in turn, will impact overall demand patterns. Modelling on smart grids has identified that it is a more cost effective strategy than conventional method. The results from savings on network costs, increased economic growth as identified by DECC and Ofgem in the smart grids roadmap, Increased energy security (Ofgem, 2012d; DECC and Ofgem, 2014).

The responsibility of the system operator to ensure security of supply is clear. What is less understood is the future role of the system operator and how a decentralised electricity system would impact upon it.

10.5 Role of Big 6 Energy Companies

The greatest change, arguably, could come with the role and responsibility of the big six vertically integrated energy companies. The current role of energy companies in the security of the energy system is complex. Each of the energy companies have different generation and demand portfolios, therefore, they would have different requirements of the system. Many of the electricity company's actions are regulated through Ofgem and controlled through specific mechanisms implemented by the Department of Energy and Climate Change. However, the scale of the big six does mean they have considerable lobbying power, they are still ultimately controlled by the need to grow their business in the interests of their shareholders.

There was a consensus among many of the interviewees that the security of the electricity system has been left to the market. This idea has also been reiterated by Government in the EMR and energy security strategy documentation. However this may not always be the best option.

> *"they [i.e. Government] wouldn't tackle food security via control of the supermarkets." Interviewee 6 MBS*

As it is the large energy companies who dominate the wholesale markets it is conceivable that the large energy companies should take certain responsibility to ensure security of supply. This ethos has been used in other areas of responsibility.

However, if it was seen as being in the best interests of the company, the energy companies could cause difficulties for energy security. Other than having a contractual obligation to their customers, it can be considered that the energy companies have no role to play in energy security.

A decentralised energy system, however, would likely reduce the 'power' held by a single energy company. The obligations would be socialised between the larger numbers of energy companies involved in the system. This would reduce the security risk on any specific company and generate more flexibility.

> *"Greater decentralisation brings less and less immediate accountability and responsibility on each of those participants for delivering the overall attributes of a secure system." Interviewee 31 CSBS*

The idea of reducing the responsibility for each energy company is discussed in the quote by interviewee 31. The participant's point of view is that the electricity system currently relies on the energy companies to provide energy security and that they therefore should be provided with a greater role and responsibility. However, this was backed up by interviewee 19:

> *The small generators do not have to provide any compulsory balancing to the system operator. Interviewee 19 RBS*

Therefore, it is clear that the rules and regulations would need to change the decentralised electricity system. However it is clear that ensuring energy security is not a priority for the main energy generation companies.

Although utility companies probably have the greatest ability to impact on the electricity system that role and responsibility within energy security is limited as they are dictated by the policies and mechanisms set by Government and the interests of the shareholders.

10.6 Summary

The governance of energy security is developed by and therefore the responsibility of a network of stakeholders working together. This section has identified the perception of the roles and responsibilities of the main energy system actor group in ensuring the security of the energy system. It has also looked at how these roles and responsibilities may change in a system of higher levels of decentralised electricity generation.

One of the first points to note is that energy security can be considered an intent rather than an outright policy. Therefore it is the energy policy measures which have to be implemented and carried out (Chester, 2010). Analysis of energy security is far more complex than it seems. In addition to this the multifaceted nature of energy security means that specific aspects of security would need to be considered. For instance the physical properties of security supply such as network balancing, electricity capacity levels matching demand and the risk of any external threats on the system are all important aspects of energy security. However, other issues need to be included, such as being able to find the investment required to meet future demand levels. This could mean having the appropriate market system generation or the appropriate regulatory system in order to establish connections in specific areas. Each of these specific aspects of energy security would therefore be attributable to a specific stakeholder. Ensuring balancing and settlement code is in place could be considered to be the role of

ELEXON which ultimately has to be set out by Government. One of the salient points in this research is, definitions of energy security (specifically when associated with Government) are often dominated by quantifiable aspects such as security of supply. However, this thesis argues that a broader definition of energy security is required which incorporated the non-quantifiable and longer term aspects of the electricity system future.

Throughout the process of the research there has been one common perspective expressed by the research participants. That it is the responsibility of the UK Government to ensure that overall energy security is achieved. Therefore, there is a hierarchical structure in terms of the governance of the energy system, where each of the stakeholders within the UK electricity system look to the Government to provide the policies, mechanisms, rules and incentives for the energy system to operate. This is in contradiction to the modern governance theories discussed in section 6.3.1.

However, the UK Government can be considered to concentrate on utilising centralised electricity generation to deliver energy security. Secondly, Government would not be the best placed stakeholder to deliver on the broader definition of energy security with the exception of security of supply. Largely this is because Government tends to operate on a timescale that is short (based on electoral cycle) and this short timescale is inappropriate for energy security. The UK Government, as identified in section 4.1 is focussed on short-term security of supply issues as opposed to the longer term. It may be concluded that, at present, there is not a single stakeholder best place to deliver energy security. Rather responsibility falls to the network of all actors from consumers to the main energy companies and Government. In order to achieve energy security, there would need to be a better understanding of the broader issues including a better perception of what different stakeholders can achieve. This would require a very different response to the current perception of energy security being the responsibility of Government.

The perception that Government is the sole stakeholder responsible this has further impacts. As discussed previously, the current energy system needs to move to one which is low carbon and affordable, achievable through a centralised program utilising nuclear power and carbon capture and storage technologies or a decentralised program where renewable generation would be the dominant technology. However, the Government is unlikely to express a preference for any specific pathway as it would restrict investments in alternative, possible futures.

Throughout this thesis the discussion has been around either the move to a low carbon centralised or decentralised generation profile. Therefore, the Government's preference to operate with a mix of large and small scale generation will influence the energy system development. The governance theory suggests the responsibility of energy security falls on the actions of a network of stakeholders working together for a desired outcome. However the perception of the research participants identified Government as the principle stakeholders. Therefore, with a perceived power, stakeholders look to Government for direction on the future of the electricity system.

A move to the system of greater levels of decentralised electricity generation would undoubtedly change the governance structure seen today. From discussions with stakeholders operating in the electricity system, it is unclear exactly how all of these changes will arise. Some changes are more widely discussed by the interviewees than others, such as whether it is likely that there would need to be greater involvement by the distribution network operators in terms of network management. An increase in small-scale generation with the distribution system will make balancing the local networks more complex. As the decentralised generation increases on the network it will no longer be able to be considered negative demand. Increasingly the network will need to be able to redistribute the increased electricity production, possibly outside the local network. This would impact on the role of the system operator who will experience supply form part of the network it had previously only seen demand.

Another change in the governance of a decentralised electricity system would be the role of the consumer as discussed in greater depth in the next chapter.

11 Role of Consumers

The previous section discussed the roles and responsibilities of stakeholders in ensuring energy security. It looked specifically at the role of Government, Ofgem, network owners, the System Operator and the big six energy companies. It identified Government as a principle stakeholder responsible for energy security albeit the UK Government holds no assets in generation or transportation of electricity. Having said this, it is clear that Government sets the agenda and policy for the other players to operate within. This signifies a perception of a hierarchical structure in the governance of the electricity system, which is contrary to modern governance literature as discussed in section 6.3.1. The previous section looked at the Government, market and regulatory-based stakeholders without discussing the impact of consumers, specifically their behaviour, which will be discussed in this final chapter.

A key point to make is that current energy security is dominated (incorrectly) by the ethos of supply meeting demand. This has been backed up by the perception that consumers (as a group) have little or no role in energy security. However, the demand aspect of the energy system has the ability to be a vital tool in the balancing of electricity supply and demand. Although, there are mechanisms in place now and for the future a decentralised electricity system has the ability to promote, complement, and speed up these mechanisms and ultimately change this demand/supply paradigm.

The technological characteristics of the electricity system can be considered to shape the role and behaviour of individuals and businesses. At present consumers can be considered as disengaged; their focus, predominantly, does not go beyond the payment of energy bills and generating plants are out of sight and out of mind (GOfS, 2008; NESTA, 2010). The move toward a decentralised energy system will involve a greater interaction of smaller stakeholders, potentially including the consumer, be they individuals or businesses.

By increasing the level of decentralised electricity generation, conflict with the current grid infrastructure is likely to occur (McDonald, 2008). This is because the growth of distributed generation puts pressure on the distribution network the network's stability, power quality and the operational challenges implied by a shift from a predominantly large scale to small-scale generating technology. Therefore, consumer response can have a positive impact on a decentralised electricity future.

In order to help provide a reliable supply of electricity there are two possible options. The first is to establish enough reliable backup storage such as flywheels pumped storage and compressed air to balance out any unforeseen anomalies which may occur (Gottwalt et al., 2011) (see section 3.2.1.4). However, these technologies are currently expensive to build and it is very difficult to model the number and scale of their use during a certain period, as a result predicting their return in the current market would be near impossible. So, a separate mechanism for funding such projects will be required. The second is a less capital-intensive method, which involves the balancing of the network through the primary dimension of demand patterns (Short, 2004; Strbac, 2008; IEA, 2008; Clastres, 2011). This includes changing the demand patterns to meet the level of capacity, requiring a greater involvement in the electricity system and additional information such as the short-term price signals for the consumers. This is one example of how demand patterns and consumer behaviour can impact on energy security and has been identified by CE Electric in the EMR consultation:

> *Customer response could also have a role to play in the balancing market, e.g. smart appliances with frequency response. But it is important to establish the cost-effectiveness of different sorts of interventions. (CE Electric, 2010)*

Having said this the impact of demand on energy security is rarely ever discussed. This section will look at whether the consumer is considered as a factor in energy security and the implications of moving to a decentralised electricity system on these applications.

As identified in chapter 5, a low carbon, decentralised electricity system is synonymous with many of the renewable technologies which are considered by their nature, variable generation sources. Therefore, the use of demand management would be beneficial for its balancing if not a requirement. Decentralisation also provides access to the inclusion of consumers, vital to the operation of demand management. This section will also look at the consumers' role in managing a complex system with a larger number of smaller stakeholders involved. Lastly, it looks at the increase in engagement that is often associated with small-scale electricity generation projects and whether there are any possible pitfalls to engaging more consumers.

11.1 Demand Management

Demand management is a technique in which demand can be controlled to the benefit of the system. In the electricity system it can be used to ensure the balancing of supply and demand, where historically this has been achieved mostly through the supply side.

At present the limited amount of demand management on the GB electricity network is achieved through the large industrial and commercial businesses alongside the Economy 7 tariff for some individual householders heating requirements (Torriti et al., 2010).

A recent DECC consultation document has shown that the UK capacity margin of around 10% is required to ensure a secure electricity supply (DECC, 2011e; BNEF, 2012). While the UK capacity margin has historically been above this level, with future threats to the energy system ensuring this level of security may come at a higher price.

The security of supply issue is seen more as a need to prepare the generation sector to withstand any likely outages (DECC and Ofgem, 2012). This preventative approach is achieved by providing additional generating units which are able to be dispatched, ensuring security under any situation. Therefore, the system is able to cope with almost any outages but at the expense of optimum efficiency.

The advantage of this simplicity comes at the expense of increased costs (Strbac, 2008) because the lowest cost plant is more likely to operate throughout the year, the higher cost generators would operate for only a few hours a day. Therefore, to keep the higher cost plant available for these peak times there would need to be enough incentive, meaning additional costs to the electricity system.

Demand management is the process by which the demand profile can be adapted to meet the needs of the system. The demand profile of the electricity system includes the changes in consumption over a certain time-scale, be it a day, month or yearly fluctuations. The impact of these peaks and troughs in consumption mean that excess capacity is needed to meet the maximum level of demand, though it may not always be utilised. By managing demand, the peaks and troughs can be reduced. However, demand management requires the involvement of the consumer to a greater degree than at present. Therefore, in order for this to occur additional incentives will need to be put in place by Government.

> *Matching supply and demand is an important principle running through the proposals, and the Government should engage more fully with all parts of the electricity industry to ensure that both generation-side and demand-side flexibility are cost-effectively utilised. (CE Electric, 2010)*

In order to develop a system of demand response there is a need for the UK Government to promote mechanisms and incentives, which will promote the demand side as a tool in balancing.

The quote from CE Electric shows a perception of some research participants looking toward Government to develop the structure and processes for other stakeholders to follow, such as the consumer group, to develop and ensure the security of the system. However, UK Government modelling is dominated by economics and quantifying the different aspects for the future.

> *Whilst it is difficult to quantify exactly how much of an effect these types of demand-side measures will have it is possible that they could be significant. (SSE, 2011b)*

The issue identified here is that quantifying demand response may not be easy. The costs to networks and consumers could be estimated. However the response to the mechanism is not so easy to predict. This measuring of demand side measures has been identified by SSE in the Energy Security or independence Consultation.

An increase in decentralised generation has the ability to involve the consumer in the energy system to a greater extent. Strengers (2012) discusses the idea of changing the consumer– supplier relationship, where decentralising the energy system can change the role of the consumer, making them, no longer passive recipients at the end of a network of infrastructure (Hogget et al., 2011). They would become active stakeholders managing their own practices and involved in the dynamics of supply and demand (Van Vliet et al., 2005). This can be the consumer actively purchasing generation equipment or being able to see the generation technology operating in their area increasing the direct relationship with the energy system. This offers a channel for increasing the information the consumer receives. There are also financial incentives which are associated with the micro generation technologies through the FIT export tariff which is currently set at a low rate and has little impact but has the ability to increase. Along with the micro scale technologies, the consumer is able to monitor the generation and consumption levels of their individual household, providing the technological aspect of demand management.

Demand management can also be considered in two different timescales: firstly short-term absorption of changes in demand, where the short-term pricing signals are used to alter the daily peaks and troughs in the demand profile. Secondly the longer-term economic changes to meet wholesale market conditions such as the availability of a particular technology. This can include the availability of primary resource such as natural gas or through changes to Governmental policies.

> *In the new world demand will be less predictable and indeed demand will have to start to hunt after generation at times so when the wind is available that is when we want to have demand." Interviewee 13 GBS*

Research participants rarely discussed demand management in a security context. One of the only references made is to the future of the electricity system with the inclusion of variable generation, as shown by interviewee 13.

What interviewee 13 identifies is the concern over future balancing in a system of high levels of renewable generation. This is an indication that demand response will only be required if supply cannot meet demand. However, as discussed in section 3.2 the future of the electricity system is likely to be very different especially in terms of demand. If the future were to include the electrification of heat and transport then there will likely be higher peaks and troughs thereby make demand management more of a priority. This is an indication that demand management could be a requirement in a centralised system as well as a decentralised system.

In all aspects of demand-side management the end goal is to either move or reduce peaks and troughs of the electricity demand profile and ultimately increase the electricity system efficiency (Clastres, 2011). In addition, any overall reduction in demand through demand management can also lead to a reduction in carbon emissions (Strbac, 2008 Faruqui et al 2009; FERC, 2009; Clastres, 2011). Therefore it is clear that demand management can have a major impact on energy security through balancing and the efficiency savings. If demand management clearly promotes a secure system then the question for this thesis is; how can a decentralised electricity system influence or promote demand management?

> *"If the market is very complicated and very difficult for people to understand if you're looking to backup capacity, part of me would think by the time you have thousands of people offering decentralised generation would have a pretty responsive demand-side." Interviewee 5 GBS*

> *"Because decentralisation empowers consumers we are in good shape to get the demand management and therefore the energy balancing which we could not have got with a supply type production strategy." Interviewee 6 MBS*

There are clear arguments to suggest that an increase in the level of decentralised electricity generation implies an increase in the need for demand management (Hurley et al. 2013). This is seen in the literature (Strbac, 2008; Torriti et al., 2010) and from interviewee 5 and 6. The two interviewees quoted above are discussing decentralised electricity generation as being synonymous with the application of demand reduction. However, simply increasing the level of decentralised electricity on the system will not intrinsically mean an increase in demand management. Demand management would require a greater level of information to be passed between the consumer and provider, the roll out of demand management technologies, and short-term pricing signals for consumers.

At present policy mechanisms for this are in place for large consumers to play a role in the demand management through the use of interruptible tariffs, whereby the business which signed up to the mechanism can be cut off at times when demand is high and supply is low (Torriti et al., 2010). However, interviewee 12 discusses the uptake of this as low (at 3.8% (Ofgem, 2010e)), due to the impact on industry of having to reduce consumption at a moment's notice which would cost more to the business than the savings made.

> *"We have already seen that in recent history the demand side response has not taken off, because, National Grid may say, we will offer you a contract and if you can say that you will turn off something with half an hour's or 4 hours notice we will pay you X. Big businesses will say well we can't do that, its going to cost us more money to do that than not. So there has to be more of a dialogue between network users, how they use the network, what they are prepared to do change their abilities, how much of that can be done passively, how much can be done pro-actively, by customer." Interviewee 12 CSBS*

This identifies that there is a need for communication between the consumers and the system operator. It shows that simply passing information down to the user is not enough. There needs to be more involvement and a greater level of inclusion and action from the consumers. The issue with the current interruptible tariff is that there is a high level of uncertainty over when a cut off may occur and very little control for the consumer.

Another option is to use a real time pricing mechanism, where rather than cutting off the consumer at times of low capacity margins, the cost of electricity would be designed to reflect the level of security of supply, where if the generation capacity on the network is low, the end price would be high and vice versa letting the consumer decide when they increase or decrease consumption. The time of use tariffs means that the consumer is given the choice whether to pay extra for continuous security of supply. As discussed in section 4.3 a dynamic and flexible electricity system is key to ensuring security. The ability to respond to any abnormalities and fluctuations which may occur in electricity pricing key to providing flexibility and therefore security (Strbac, 2008). Real time electricity pricing has the ability to impact on the operation of the system through changing behaviour. However, real time pricing in some circumstances be discussed as not being effective at the moment.

> *"We did a quick You-gov survey around consumers at that point, early stage of 2008 to try and get a quick sense of consumer understanding of how much extra are you prepared [to spend] for your electricity to be lower carbon. We didn't ask questions about security of supply because it was a concept which would be quite difficult to get across. But it was quite clear that the consumer at that stage didn't see very much reason to be paying anything more for low carbon energy and I think actually for security they wouldn't perceive what value they should attribute to secure supplies. That has been consistent, not surprisingly since that point." Interviewee 31 CSBS*

This may be because in order for real-time pricing mechanism to have an effect on the demand profile you would need to establish the right pricing structure and how much consumers might be willing to pay for a secure supply. As interviewee 31 discussed, this is not easy to identify. Just as the majority of the surveys are around the low carbon energy system, many of the information campaigns also discuss carbon emissions rather than security. This lack of focus on energy security information campaigns could be because energy security is not currently considered an aspect of the energy system which the consumer can be involved in. The complexities around the concept mean that a discussion with the general public would be very difficult. It could also be that carbon emissions provides a moral question where the developed world is considered to be responsible, whereas security has always been a state run aspect of the system. Therefore, finding the cost of electricity security to consumers, both the individuals and the businesses, would be useful. However, as identified by interviewee 31 in the previous and following quotes this may not be easy.

> *"How much is a consumer prepared to pay for security, does the consumer even understand the concept of security" Interviewee 31 CSBS*

For this to occur the consumer would need to firstly understand what a secure energy system means to them (Damigos et al., 2009). However, as, interviewee 28 (CSBS) identified *"[Energy Security] is rather a vague construct that means different things to different people".* Therefore, the concept of energy security may be difficult to grasp on top of which, the concept would be different between different persons. However, the question is, how much are consumers willing to pay for the security?

> *"They said in an ideal world with smart tech and smart metering actually the individual consumers will be able to take a look at how much of a risk they wanted to take with their supply and pay the capacity premium. So if I'm sitting at home and I don't mind power cuts I could benefit from saying I will just pay for energy and I am not going to over pay for ensuring capacity is available." Interviewee 17 RBS*

> *"one of the other things we thought is that local involvement might make people more concerned and appreciative of the value of energy because there has been an issue. So far it has not exactly been to cheap to meter but have people really been playing the true cost of what they want in terms of investing in the future and the answer is probably no. So it comes as a shock when they have to pay more." Interviewee 14 GBS*

This may be true with how consumers, particularly individual householders, view energy. Its ubiquitous nature means that energy may be seen as a necessity and should be delivered by Government at a reasonable cost. Therefore evaluating the cost to the consumer should be a balance which means they are not overcharged but at the same time consumers do change behaviour to react with the price signals.

> *"So the cost of making the distribution networks truly smart grids is an awful lot less than the cost of putting in place copious amounts of copper the quadrupling which you would need to do to allow it to continue to operate in an unconstrained manor. If you could actually start to shift demand around you thereby avoid this investment." Interviewee 14 GBS*

Not only can the cost of security be difficult to explain, the costs involved in setting up a demand response system are also complex. In order to provide an active demand system the information provided between the consumer and provider would need to be increased. Technologically the current distribution and transmission networks are fast approaching the end of their specified lifetime. This means that a significant proportion of these networks are due to be replaced. This opens up the opportunity to upgrade networks with the ability to enable technologies such as demand-side management to operate (Strbac, 2008).

> *"Technically, it just needs to make sure that the right incentives are put in place for the decentralised providers of energy to offer the services needed to run a stable grid." Interviewee 3 MBS*

> *"The DNO's would be happy to become active as long at the money is there." Interviewee 30 CSBS*

In addition to this, a market-based stakeholder identifies that as long as the incentives are in place, theoretically that should be no problem for the DNO's to fulfil the role of an active network operator (interviewee 3). This idea was also confirmed by a civil society stakeholder (interviewee 30).

However, as discussed in the previous chapter the DNOs at present have very little role in energy security. If they are to become active network managers they will need to identify this at an early stage. The DECC and Ofgem smart grids forum at least identify that the roles of the DNO's will change in a future of low carbon generation. In addition to this they identify that the consumer will be given a more active role in the electricity system:

> *The roles and responsibilities of consumers in this type of energy system will be different allowing them to participate more actively in the energy market place (DECC and Ofgem, 2014: pg. 9).*

The future profile of the energy system will likely be decided by the best investment strategy which meets the goals set out by Government. Interviewee 5 (government based stakeholder) discussed this understanding of what the future energy system will look like and how this will impact on energy security.

> *"if you're looking to backup capacity part of me would think by the time you have thousands of people offering decentralised generation you would have a pretty responsive demand-side. If we have a pretty responsive demand-side then that changes the security question quite significantly. At the moment there is some demand-side response clearly in terms of those people who have interruptible contracts but it's pretty price inelastic." Interviewee 5 GBS*

Once again this government-based stakeholder identifies a link between demand response and decentralised generation. They also link it directly to energy security realising its benefits. This is a clear connection between the decentralisation of electricity, demand response and energy security. This is a response from a DECC employee. However, as identified by Friends of the Earth is the EMR consultation, where this connection between demand response and energy security has not yet been capitalised upon.

> *Proposals set out in DECC's EMR consultation document [...] are geared towards building more electricity generating plants, rather than cutting the need for them to the through energy efficiency, smart grids, storage and connections with other European country (Friends of the Earth, 2010)*

The demand management is an underutilised dimension of enhancing energy security. The overall reduction in consumption from active demand management will provide a reduction in costs for additional infrastructure (Poudineh and Jamasb, 2014) at the same time as providing an additional level of security. The level of demand management implemented will impact on the benefit but also the overall cost to the consumer. However, in a system of highly decentralised electricity generation some of these demand management benefits may be achieved from the additional consumer engagement that a decentralised electricity system brings and effectively reducing the cost of implementing a demand management scheme.

The perception of the research participants clearly shows that demand management can be beneficial to both centralised and decentralised low carbon electricity system. Therefore, the future low carbon electricity system is likely to see some form of demand management. However what is also clear is that quantifying the benefits of demand management is not easy. This means, for Government, setting out the right incentives which will balance the cost of implementing demand management to consumers with the savings made implementation. One of the difficult aspects in this is from consumer behaviour, this includes the benefits of engaging consumers to a greater extent.

11.2 Engagement

The idea of engaging consumers in the energy system is not a new concept. This has been discussed by environmental advocates since the 1970s in order to address issues such as self sufficiency and empowerment (Lovins, 1977; Willis 2006; GOfS 2008). Current engagement of consumers in the electricity sector is well known to be limited, especially for the individual householder where often the only interaction is with the electricity bills (and often they are paid by direct debit) (Owens & Driffill, 2008). Larger businesses, depending on their size, have a greater ability to interact with the energy system through specific contracts within their energy companies, however, they still have only a limited level of control.

Promoting the level of engagement of consumers in the energy system in some ways is similar to the demand management process discussed earlier through the introduction of greater information and technology for consumers. But realistically engaging energy consumers means providing them with more power (the ability and desire to impact on the energy system).

Throughout the process of the primary research the participants were asked how the engagement of consumers could affect the security of the electricity system. The response across each stakeholder group was almost unanimously that greater inclusion of the electricity consumer in the system it would not adversely affect security levels. Often the discussion over the engagement of consumers provided a positive outlook on energy security which coincides with the literature (Sauter and Watson, 2007; Chappells et al., 2000; Wolfe, 2008; Chmutina and Goodier, 2014). By engaging consumers in the electricity system they may be able to understand the impacts which occur on the electricity system and alter their demand accordingly, also the inclusion of consumers may open up the investment portfolio for electricity generation. However, it was not always seen as a positive.

"This is not just information campaigns it's also the technology, the smart meters. If delivering those solutions, the smart meter, the engagement is actually more expensive" Interviewee 12 CSBS

There were a few examples discussed when engaging the consumer could pose a problem due to the increased costs incurred. In order to increase the 'power' of the consumer, various strategies would need to be put in place, including the technology that will provide them with the ability to change, and the understanding of how they should alter behaviour which would provide the desire to change. These methods of engaging consumers would obviously require investment to implement.

The increase in cost of engagement would likely be offset by the savings made from a more efficient electricity system. In addition to this, engagement impacts on further aspects of the energy system such as fuel poverty and climate change through an increase in efficiency (Preston et al 2009). Although, without conclusive evidence of this, the results cannot be confirmed (Thøgersen and Ölander 2003). In addition to this, changes to the role and responsibility of the consumer would occur.

"It depends on whether they are taking on all the risk. Or whether you are actually saying well no they are not going to have to take on all the risk if their lights go out" Interviewee 18 MBS

The increase in the level of engagement would likely provide the consumer with an increase in their level of perceived power. Interviewee 18 discussed the idea that, if the consumer ends up with greater power in the energy system they will also need to be willing to take on the risk to energy security that comes with that.

In fact they are taking on very little risk if the system operator would ensure sufficient backup capacity. An increase in the electricity consumer engagement does not automatically mean increased responsibility. The way in which the policies, regulations and mechanisms are developed will develop the stakeholder responsibility. The responsibility associated with the current energy companies for energy security is limited as discussed in section 10.5. It is more of an understanding of the costs involved in ensuring security and the consumer being able to follow the pricing structure so that they adapt to what the electricity system requires.

In the current electricity system, the consumers understanding of energy bills can be considered low. An example of this is around the cost of renewable and green policies, where the understanding of consumers can be considered very different to that of the opinion amongst industry experts. An example is the cost of the Renewables Obligation to the consumer bills. DECC states that at present the RO adds on average £26 to the consumer bills and by 2020 it will rise to just over £50 (DECC, 2013d). The savings from green energy policies are also projected to save the consumer £94 per year by 2020 as shown in Figure 11-1 (DECC, 2012f) also see section 2.4.2.

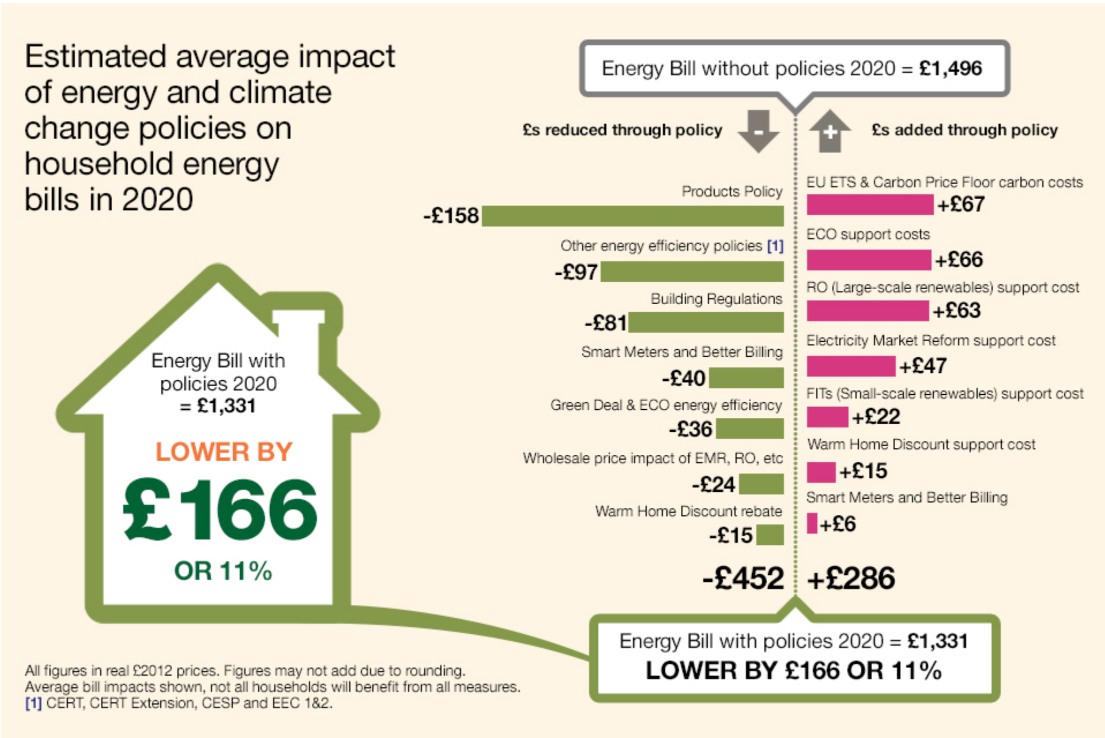

Figure 11-1 Showing The Estimated Impact of Energy and Climate Change Policies on Average Household Energy Bills in Year 2020 (DECC, 2013d)

Although the savings from green energy policies are clear, the message was not publicised in the media meaning information provided to the consumer is not complete (Stevens, 2011; Shankleman, 2012). Headlines such as 'What's fuelling your energy Bill?' and 'Green policies are costing Britons the earth' are often highly selective in their use of facts and bias (Panorama, 2011; Porter, 2012; Groves 2012). Having said this a recent YouGov survey found the majority of consumers (55% for wind and 74% for solar) are still asking the Government to increase the use of wind and solar power in the electricity system (YouGov, 2011; Parliament 2012b).

> *"in one hand I see it as good because it means that people are actually starting to recognise the value of power which I don't think we do at the moment. We flick it on at the switch and it works. If you are producing you are becoming more [aware] of your consumption of it as well." Interviewee 13 GBS*

One of the main issues with looking at the context of wide scale engagement is that there's very little practical experience which can be analysed and discussed. However, what is apparent is the current gradual move to greater levels of engagement through renewable energy projects.

11.3 Summary

At present it is clear that consumers play a very limited role in energy security. The connection they do have is through the interruptible tariffs and their investments into small-scale technologies used to offset electricity bills.

The majority of supply security is achieved by ensuring a high level of capacity. The higher the level of peak demand, the higher the cost of the generating plant. The future of the electricity system is likely to introduce an increase in demand from electric vehicles and the electrification of heat. Therefore it is likely that peak demand will increase. If the usual model for meeting demand is used this will increase the cost to the electricity system dramatically.

Another form of meeting this demand will be required. One answer is to develop and invest in additional storage technologies; however, these are also likely to be very costly. The classical methodology to meeting supply and demand is rarely through the demand-side. This paradigm needs to change and demand management needs to be utilised to its full potential.

Managing demand can take on different forms, from using technology to information campaigns. Interviewees in this research identified a connection with the decentralised electricity generation and demand management. If there is an increase in variable generation it will be necessary to engage consumers in the system and any route is through demand management initiatives.

It is likely that a low carbon, centralised electricity system will require some forms of demand management. This is because the future will include greater demand levels and an increase in the number of inflexible power plants such as nuclear power that struggle to follow demand. Furthermore a decentralised electricity supply system would increase the complexity of balancing the network. This would likely be the responsibility of the DNOs. Demand management would have the effect of reducing the extremes and help reduce the complexity of balancing the system.

One of the counter arguments to consumers increased action in the electricity system identified by some research participants was down to its cost. There is inherent value in active consumers but if this value is swamped by the cost of making them active that was not seen as worthwhile. However, many of the benefits of decentralised electricity system may not be quantifiable specifically when discussing consumer engagement. For example, what is the financial benefit of individuals becoming interested in where electricity comes from? Therefore trying to quantify the impact of energy security may not provide the whole picture and thereby diminish the role of decentralised electricity system can play in energy security.

Finally, moving to a decentralised system was identified as engaging the consumers and hence developing a change in their behaviour. Not only does this help to modify demand but it encourages them to invest in the system.

12 Conclusion

12.1 Introduction

The ubiquitous nature of energy within society has meant that it is embedded in nearly all the current issues facing the world today. Social, political and environmental problems are currently, and will remain, interconnected with energy issues. These can include links between low-income households and fuel poverty, the impact of energy prices on energy intensive industry, the geopolitical implications of fossil fuels and what could be considered the most dominant issue for the energy system, the impact of carbon intensive electricity generation on climate change.

Therefore, energy may not be considered as a commodity but as a requirement for commodities to function, signifying that energy is a primary driver behind much of society's needs and wants (Schumacher, 1973; Goldthau and Sovacool, 2012).

The principal motivation behind this thesis is based on the understanding that the energy system will need to change in order to adapt to issues such as climate change, resource depletion and the changing political and economic climate. The future energy system will need to face each of these issues at the same time as providing a secure approach to energy generation delivery and consumption.

This thesis discusses the move to a predominantly decentralised electricity system, specifically looking at the changes this would bring to the governance of energy security within the electricity system.

Two research question were posed:

- **How will a decentralised electricity system change the governance of energy security?**
- **Who is responsible for energy security (not just supply)?**

In order to answer these questions, defining the main themes raised in the research is required. This thesis has called for a broader definition of energy security to include:

- **The provision of reliable energy supplies for primary fuels and their delivery**
- **The requirement for the energy system to be flexible and dynamic in order to respond to unforeseen future changes.**

- **A requirement for the protection of the fuel vulnerable in the face of energy price rises and confidence that the economy would not be undermined at the cost of maintaining energy security.**

This definition was achieved by identifying the key dimensions of energy security including the drivers, issues, risks and impacts. From these dimensions a set of 'requirements' were found which theoretically would provide energy security now and in the future. These requirements define the concept of energy security for this thesis.

When using a broader definition of energy security such as the one in this thesis the current approach of a centralised electricity system would not be the best-placed model for meeting the UK future energy targets as well as providing energy security. This thesis is arguing, that a decentralised electricity system would be able to provide certain aspects of energy security which a centralised electricity system cannot.

Decentralisation of electricity generation requires two main properties. F**irstly, a technological aspect, where the generation plant is connected either to the distribution network or off grid at a location close to the point of use. Secondly, the ownership aspect, a decentralised electricity system results in an increase in the number of stakeholders with ownership of infrastructure.**

12.2 Outline of theoretical approaches

In order to develop an understanding of the move to decentralised electricity, the concept needs to be placed within a theoretical framework. This thesis sets out the different modern approaches to transition theory, focussing specifically on energy and electricity systems. This begins by examining the current lock-in to a centralised approach and the difficulties in developing decentralised electricity technologies, policies and system structures. This also poses the idea that the policies and system structures presently exist in the centralised system lock-out a decentralised approach to electricity generation.

There is a range of transition theories from transition management to strategic niche management which are discussed. It was identified that the multi-level perspective could be the best approach to discussing the transition theory from centralised to a decentralised electricity system. The multi-level perspective is made up of three aspects: the landscape, the regime, and the niche innovation. This perspective provides a comprehensive approach to a complex arrangement such as the electricity system.

The landscape factors may not be specific to the system in question and therefore would be unlikely to be solved by the system change. For the purpose of this thesis the landscape factors would include climate change, energy security and energy affordability. These are the main challenges as set out by the UK Government.

The regime, which is driven by the landscape factors (but not controlled by them) for the electricity system, can be considered as the stakeholder groups (such as the energy companies, Government, regulators, network companies and consumers) and the rules and incentives (including Government and company policy, market arrangements and subsidies and regulation) (Rotmans and Kemp, 2001; Smith et al, 2005).

The niche dimension in the transition from a centralised to decentralised electricity system introduces a large number of smaller actors working outside the marketplace trying to break into the current system.

However, one of the criticisms of the multi-level perspective is that it lacks the definition of how governance can impact on a system transition. Therefore, this thesis discusses the governance needed for this particular transition. Governance is defined with two interlinked aspects: the organisation of stakeholders within the electricity system and the rules and incentives, which enable the system to achieve the desired outcome.

This thesis identified a range of governance models, including the classical theories where the hierarchical structure would include government as the main decision maker and then power is filtered down to the other actors and actor groups. These classical theories purely take the viewpoint that change occurs as a result of the actions and policies of government (Rhodes, 2007; Rotmans and Loorbach, 2008; Pahl-Wostl, 2009). Historically, academic research has focused on the policies and actions of government, however, this thesis is goes beyond governance as government. It utilises a more modern approach to governance where the assumption is that that societies are governed by the efforts of a number of actors and entities made up of both public and non-public groups (Kooiman 2003; Rotmans and Loorbach, 2008). This means government is merely a single group of actors who have the ability to influence a system.

These modern governance theories suggest that 'responsibility' or 'power' occurs in a non-hierarchical structure and it is the effort of a network of actors who shape the system.

Through considering different theoretical approaches, from the structural approach to the network analysis, this thesis has defined governance as: **the organisation of stakeholders within the electricity system as well as the rules and incentives which enable the system to achieve the desired outcome.**

The rules and incentives identified here are the detailed policies that are implemented and the mechanisms designed to achieve the desired outcomes. The rules and incentives are co-dependent on the stakeholders. The networks of stakeholders create these policies and mechanisms. At the same time the policies and mechanisms can create and develop the stakeholders. It is the ever-changing development of the stakeholders and their relationships which adapt the policies that advance the electricity industry. The relationship between stakeholders provides a discussion of power between each of the actors and actor groups. The power of an actor is defined by their ability and desire to drive change (Preble, 2005).

Foxon et al (2009) discuss the relationship of power between different actor groups looking at civil society, market-based stakeholders and Government organisations. They consider governance patterns for transition pathways for a low carbon future in the UK. In a similar way Parag and Darby (2009) have developed this approach to examine the main groups of actors involved in reducing carbon emissions. This method of utilising actor groups to model the governance of energy security in the GB electricity system is used in this thesis. However, it was felt that both Parag and Darby, and Foxon et al lacked an important actor group relevant to this thesis. This being the regulatory based stakeholder, which includes the network operators for both transmission and distribution. Their responsibility in energy security (specifically the DNOs) may not be viewed as central at present. However a system of decentralised electricity would result in a far greater role in the balancing and operation of the electricity system. This relationship is presented in Figure 6-7.

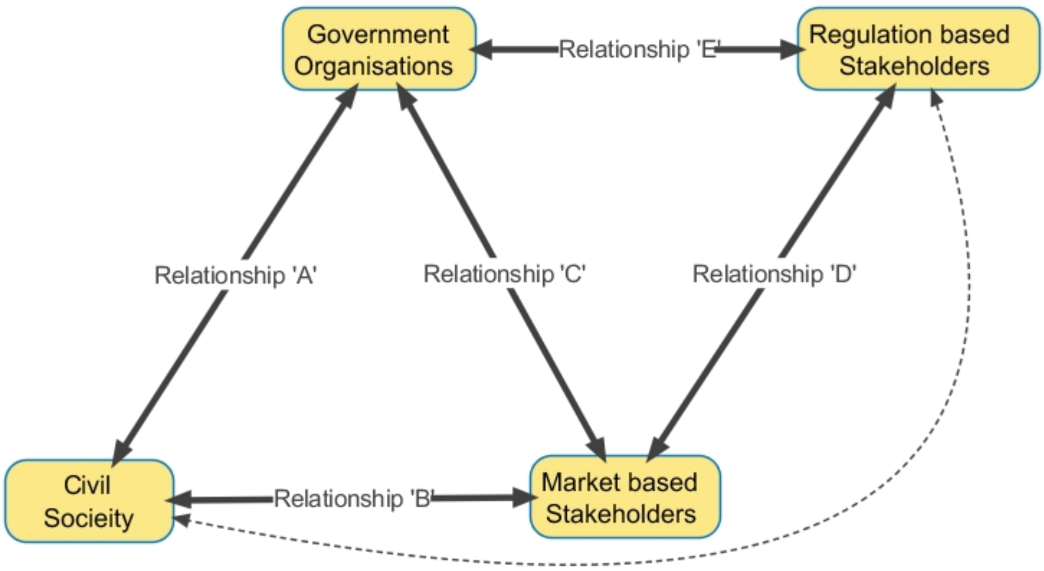

Figure 12-1 Main groups of actors involved with the governance of energy security (Parag and Darby, 2009; Foxon et al 2009).

When this concept of power and relationships is applied to the electricity system a third aspect arises, the responsibility for energy security. For the purpose of this research, responsibility is defined as an actor, or group of actors, who have the ability and obligation to act. This means that the level of power an actor holds can have an impact on their responsibility (i.e. low power, low responsibility and vice versa). The responsibility of a stakeholder can be set out in legislation giving them a legal responsibility toward a particular dimension such as energy security. However, this does not mean they have overall responsibility as the definition of energy security can change depending on the stakeholders. For instance, the UK Government has a legislative responsibility toward ensuring energy security, however the definition they use focuses too heavily on security of supply rather than the broader definition of energy security used in this thesis. The UK Government also delegate different aspects of energy security to other stakeholders and by extension makes them accountable.

Therefore, theory would suggest, the governance of energy security is defined through a range of actors rather than a single actor or actor group. However, it was clear from the research undertaken that overall energy security was viewed as the responsibility of the UK Government, with the majority of stakeholders looking to Government for guidance especially in terms of investment security. This achieved by the setting of Government policy, which was also criticised for not providing enough clarity for the future. This means that the theory that governance is apolitical does not meet the reality which shows the UK Government is perceived as a central actor in the energy security debate.

12.3 Key Points

The outcome of this thesis identified four key points in the governance of energy security in a decentralised electricity system. The first is that a decentralised electricity future would introduce a larger number of small investors, who in a centralised system would not exist. The second key point is, the UK Government is responsible for security of supply[27] and their actions are focused on centralised electricity technologies. The third point is that energy security (in its boarder definition) is the responsibility of a network of actors working together. The fourth point is that current energy security is incorrectly dominated by supply meeting demand.

12.3.1 Investment In a Decentralised Electricity System

The first key point, that a decentralised electricity system introduces a larger number of smaller investors who previously would not have existed, can be split into two separate aspects:

Firstly, a decentralised electricity system would provide a different avenue for investment. This means a there would be a change to the scale and flexibility of each investment project and to the type of investor.

The large scale projects the current centralised electricity system requires, requires that, in order to increase the level of capacity on the electricity system, a large amount of funding is required. The research participants identified that achieving this funding not only can take a long time but it can also cause issues if the project comes into difficulties (such as a loss in faith of future returns for the investor). This brings up one of the dominant aspects from all research participants; the UK Government needs to provide a clear signal for the future of the electricity system. The market based stakeholder specifically identified that any uncertainty in future energy policy would cause risk for investment. Therefore, demand higher returns. It could also create an issue for security as the low carbon future will require greater levels of investment. Further to this, it could be argued

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27 Security of supply is not the same as energy security see section 4.2 that large scale centralised investments would be harder to find, thus requiring greater direction and future rigidity from Government.

In contrast a decentralised electricity system can stagger the overall investment costs over a number of years meaning projects can be started in shorter time scales and can expand or contract depending on market considerations. This means decentralised projects has a lower risk level and possibly opens up he investment opportunities.

In addition, the introduction of a larger number of smaller generation plants opens up the investment portfolio to new, smaller investors. One concern of this introduction of smaller investors which was discussed by interviewee 31 (CSBS) is that the knowledge and skill level of each of these investors is likely to be lower than that of the larger investor and therefore the incentive mechanism or market operation cannot be overly complex. Therefore, easier market mechanisms for the smaller investor, such as the FIT are required. This could mean, even though small scale generation technology are able to reach market parity, they may still require a FIT type mechanism in order for the investors to understand. The issue of this is that Government would need to continue to set the price for renewable energy technology. The concern around this identified by a government based stakeholder is that these mechanisms distort the market price of electricity, thereby making electricity more expensive.

The current larger energy companies be they generators, suppliers or utilities have a large resource base in terms their knowledge and skills to operate in the electricity markets. This is a resource which smaller companies, householders or communities would not be able to match. Therefore, to encourage the small investor, there needs to be the allowance for the consumer to calculate their expenditure and returns with some degree of certainty.

The variable nature of fossil fuel markets means that the long-term costs of coal and gas can be uncertain. When this is compared to non-fossil fuel generation where the long-term running costs are more predictable, a future investment portfolio can be easily calculated. This was identified by a small scale market based stakeholder who identified that as they predominantly deal in renewable energy projects they have not had to change their end price of electricity because of fossil fuels. However, some renewable technologies do have a variable generation profile in the short-term, although when this is extrapolated over a long time period a fairly accurate predication can be made. This means that the longer term investment (over a long period) would be easier to predict.

Another option is to have a central aggregator who can operate in a complex market system on behalf of a number of small generators. The aggregation of a number of small-scale electricity generators will ensure that as a cumulative group each generator is able to get a better price for power in the market. It would also mean that all generators would benefit from lower prices made possible through the economy of scale.

One of the big advantages identified by some research participants is promoting a decentralised electricity generation investment is that it is less likely to be competing with other international projects; such as a shopping mall in Hong Kong, or whether it should be invested in mining in South Africa (Interviewee 6). Larger scale generation plants could require international investors who would look for the best financial return at the lowest risk. Consequently, the GB's large scale generation projects would be competing with other international projects.

A second aspect of this key points is the necessary investment into other technologies required for a decentralised electricity system. Low carbon, centralised electricity generation includes technologies such as nuclear generation and the use of fossil fuels with carbon capture and storage. Decentralised electricity technologies would be pre-dominantly small-scale and renewable generation generally results in a low carbon system. The small-scale nature of these installations would suggest that there would need to be changes to the way in which the markets operate as the current system could be viewed as penalising the small-scale variable generation as identified by Interviewee 6, 19 and 21.

Investment into distribution networks, at present, is regulated through price controls, (the RPI-X and in 2015 it will be the RIIO-ED1 price control). Decentralised electricity generation can cause issues to the network such as constraints in the physical lines and constraints in the ability for new generation to be connected to the network. In order to resolve any issues found with connecting small-scale generation to the networks a more forward looking approach to connection is required where the networks can predict and adapt to future requirements. At present the RPI-X provides an overly specific approach to network development (this means constraints are fixed when need arises). What is required is an approach where anticipation is used rather than a reactive methodology. This will require the new RIIO model to allow the DNO's to fund the development network areas, not to just provide access for a single project but cope with multiple access from a particular region.

An additional technical aspect of a decentralised electricity system is that there would be less activity on the transmission network. This could result in a reduced requirement for upgrading and an improved efficiency factor in moving to a decentralised electricity system. Although, this would only be true if the DNOs were to balance supply and demand in their own network. However, it is likely that each distribution network will need the back up of the transmission system to balance each local network. Further to this, any reduced activity on the transmission network would mean reduced revenues for the TNO. Although, a counter argument to this is the introduction of a supergrid, where the future of the transmission system would likely be very different. The supergrids would provide long distance links for the balancing of local sources of electricity generation.

Investment in the future of the electricity system is an aspect which touches on all dimensions of energy security, climate change and affordability. Without intelligent investment now and in the future the UK Government goals and targets will not be met. Therefore, a level of clarity is required from the UK Government in how the future of the electricity system will look. This aspect was identified by nearly all research participants. It is possible that a low carbon future could be achieved through a centralised or decentralised approach. The difference is that there are many additional benefits for energy security associated with a decentralised approach although these are difficult to quantify. However, the Government should plan for a more flexible future for the electricity system and not focus on a single model whether it is centralised or decentralised.

12.3.2 Government Role in Ensuring Energy Security

The UK Government has a legislative responsibility for ensuring energy security. This was set out in the Electricity Act 1989. The Secretary of State and the Authority have:

> *"the need to secure that all reasonable demands for electricity are met" (Electricity Act, 1989: (2) (a))*

Theoretically, overall responsibility for electricity security should be placed firmly on Government. However, there are two different aspects to consider. Firstly, a legislative responsibility is not the same as real world responsibility. Even though Government has a legal responsibility toward energy security they are likely to pass different aspects of energy security on to other stakeholders. If a particular aspect of the electricity supply industry fails, the Government could pass that accountability on to another stakeholder or actor group. As a result the Government would not have total responsibility, but needs to ensure that other stakeholders are responsible and kept accountable.

The second aspect to consider is how the Government views energy security. The UK Government has defined energy security as:

> *"ensuring that consumers have access to the energy services they need (physical security) at prices that avoid excessive volatility (price security)" (DECC 2012o pg. 5).*

Previous to this, the UK Government had not defined what is meant by energy security and merely discussed security in terms of security of supply rather than energy security. This principle has guided their approach to the application of energy security measures through the markets and effective regulation (DECC, 2012o). The UK Governments main strategy for energy security only looks at short/medium term outlook on the electricity system. This thesis argues that a much broader definition and approach to energy security is required in order to deliver the best option for energy security that will also meet the UKs future energy goals.

Furthermore, the Government's strategies for ensuring security of supply seems to be focussed on the use of centralised technology. This can be seen from the policies and mechanisms presently in place, where there is very little discussion of the use of decentralised technologies for ensuring security. Specifically the Government's Energy Security Strategy made little or no reference to small-scale decentralised technologies other than recognising their existence and relating them to a low carbon future. In addition, the Government's main mechanism in ensuring security of supply is the Capacity Market (CM). The issue with the CM is that it is focused on large scale capacity investment over long periods of time. This suggests that the Government does not view the small-scale generation as being able to deliver energy security.

Although the UK Government has a legislative responsibility to provide security of supply, the broader definition of energy security used in this thesis requires a larger number of stakeholders, working together to deliver a low carbon, secure electricity system.

During the process of this thesis an interesting response regarding the responsibility of energy security was found from the research participants. The overriding perception of the primary stakeholder responsible for energy security in UK was identified as Government. This is in contradiction with the literature on governance identified in section 6.3. The modern approaches to governance identify a change in that governance is no longer viewed as Government more that it is the actions of a network of actors. The Government may have a legal responsibility for electricity security, but the extent to which it can operate this responsibility is limited, particularly in a liberalised market with multiple stakeholders.

The Government holds some power in setting the parameters for the future development of the electricity system and therefore to some extent it is Government's responsibility to set the future system, as the stakeholders will follow the Government framework. The issue is, if Government is not clear how the future should develop then confusion may set in as to where investment should be placed.

Until recently the UK Government has identified energy security as a challenge to the energy system, without identifying in any detail the issues of energy security or provided a definition. The Energy Security Strategy published in 2012 was designed to provide a policy response to specific energy security issues in the electricity, gas and oil sectors. The Energy Security Strategy provides little discussion of the use of small-scale generation as a benefit to the energy security other than confirming that there is a framework to support small-scale renewables through the FIT. This could indicate that the Government is looking to progress along with a centralised electricity system and developing small-scale renewables more as an afterthought. This could also indicate the UK Government does not recognise decentralised electricity generation as a tool for energy security. There is a problem that without a structured approach to the development of decentralised electricity from the UK Government, investors in the sector will have their confidence undermined.

There is also a question over what type of future the UK Government would prefer. Some interviewees identified that a decentralised electricity system would mean Government "loosing a grip on the energy system" (Interviewee 3). They identified that Government may prefer 6 large companies over 1000 smaller ones. This idea was also echoed in the 2007 energy round table by the then Secretary of State for Trade and Industry Alistair Darling. The issue with this is, the perception amongst the research participants of Government as the central stakeholder in delivering energy security gives Government the dominant position. If they are looking to develop a centralised, over a decentralised electricity system then some of the benefits of a decentralised electricity system could be neglected.

However, the model of governance for energy security put forward in this thesis is that it is the responsibility if a network of stakeholders working together to achieve a desired outcome.

12.3.3 Energy Security as a Network of Actors

In the UK electricity system the dominant perception is that Government is responsible for the UK energy security. However, the UK Government may not the best place stakeholder to take on this role. The UK Government's priorities would be towards protection of the UK citizens but the relatively short-term of each Government suggests that they would be unlikely to view the electricity system in the long-term. This was indicated in much of the literature on energy security from Government where it discusses short-term security of supply issues. The EMR and Energy Security Strategy do identify long-term energy security, however, much of the discussion is still focussed on the short to medium term (see sections 2.2 and 4.1.6). What is clear from the literature and from the research participants is that there is no one stakeholder or stakeholder group that is responsible for ensuring energy security as it is defined in this thesis. Each stakeholder group may have a legislative responsibility towards a specific aspect or in the case of the Government towards energy security for the whole system. However, the legislative responsibility does not reflect the reality of the actors' roles in the electricity system.

Therefore, the group responsible for ensuring energy security can only be achieved by a network of actors and stakeholders working together to ensure a common goal. For the electricity system it is, security, low carbon and affordability, which are the priority goals. The issue with this is that there are different methodologies in which this can be achieved

The governance of the electricity system incorporates the rules and incentives which are developed through the interactions of the stakeholders involved. It is these interactions in the electricity system which will be discussed here, including the responsibility for energy security and its different aspects and the relationships between the stakeholders and their associated power within the supply system.

As identified in section 6.3 of the governance literature, a specific goal, such as energy security, is achieved through a network of actors operating within a system rather than governance by Government alone. In theory this holds true for the electricity system, where the policies and rules are created by the stakeholders as well as Government these include Ofgem, DNOs, TNOs, system operator and the energy companies.

12.3.3.1 Ofgem

As identified in the section 2.6.4 the role of Ofgem (set by Government) is to protect the interests of existing and future consumers through the promotion of competition and the regulation of the monopoly transmission and distribution networks. In addition to this Ofgem have a duty towards ensuring energy security, whereby they promote competitive markets and ensure investment is made into the supply networks.

However, the role, as perceived by the research participants, of Ofgem in energy security is one of ensuring the Government's framework is operational. This does place Government as the hierarchical pinnacle of energy security responsibility and power. In fact there was a dearth of discussion around Ofgem and its role in maintaining energy security.

This is interesting because Ofgem have a direct responsibility to ensure energy security as set out by Government. In this Government provide broad guidance in how to achieve their role in order to let Ofgem interpret their own duties. They would also have a role in ensuring the competition of the small-scale decentralised electricity generation similarly, they are also key in the development of the electricity networks which will be required to secure the future of the electricity system. A future decentralised electricity system would see a larger number of small scale investors and generation owners. This is likely to change how Ofgem achieves its duty but not the duty itself.

12.3.3.2 Distribution Network Operators

The current role of the DNO is to ensure the operation and maintenance of their network and to negotiate the connection of new distributed generation. The perceptions of the research participants were that the DNOs at present had limited or no responsibility for energy security. One role they do have is that they have an influence in what and where generation is connected to their network.

It was discussed that an increase in distributed electricity generation would result in huge changes to the role and responsibility of the DNOs, effectively giving them more responsibility and power in controlling the network. The increase in decentralised electricity generation will likely require more active management at a local level. For this to happen a change to the system operation procedures will need to occur. The indication from the research participants was that the DNOs would become more active in balancing their networks. This would suggest that the DNOs would become system operators of their local network.

When asked whether the DNOs would want to become more active the response was that they are happy to do this as long as they were rewarded for doing so.

It is likely that increased DNO involvement would increase costs, although there would likely be a reduction in costs from a more efficient network operation, the support of economic growth, and an increase in energy security (DECC and Ofgem, 2014).

12.3.3.3 Transmission Network Owner

The role of the transmission network owner is to develop and maintain the transmission network. At present there are three transmission network owners across the UK with the majority of the network owned by National Grid.

In a similar way to the distribution network owners, the transmission network owners were not seen by the research participants as contributing to energy security. Their role is to deliver electricity from the point of generation to the distribution networks. However, unlike the DNO the TNO's role will probably not change in a system of decentralised electricity other than allowing access for a reversal of load from the distribution to transmission network. It could be argued that the key role they do play is to minimise losses and maximise efficiency in the network. One of the major changes to the transmission network owners in a decentralised electricity system would be a reduction in use of the network. The impact of this would be reduced revenue for the transmission network owner. Therefore they would likely demand an increase in charges for network usage resulting in a probable increase costs overall.

12.3.3.4 System Operator

At present there is a single System Operator who has the responsibility to ensure the short-term generating provision meets demand in Great Britain. The S.O. is owned and operated by the National Grid Company who also owns the transmission network in England and Wales.

The research participants identified that in a system of high levels of decentralised electricity generation the system operator may find it difficult to meet its responsibilities. During the interviews many of the participants identified the need for the distribution network operators to become more active. This indicates that the DNOs would act as separate system operators for each local network rather than there being a single operator who would run the whole system.

Therefore, there may be a requirement for a separate system operator independent of National Grid who oversees the operation of the distribution networks and the transmission networks. There is the possibility the National Grid Company could continue to oversee the whole system as the system operator. However, the level of power and influence the NGC would hold could impact negatively on a decentralised electricity system as they are owners of the transmission network producing a conflict of interest. Therefore the recommendation is that the SO should be completely independent from the TNO and DNOs.

12.3.3.5 Energy Companies

One theme developed from the research was that energy security was achieved though the running and operation of the wholesale market as identified by one of the major market-based stakeholders (interviewee 6).

As the current small number of large companies dominate the electricity market then they could be viewed as responsible for ensuring the market runs efficiently.

However, it is Ofgem's role to ensure the effective and secure operation of the markets.

It is possible that, if it was seen as being in the best interests of the company, the energy companies could cause difficulties for energy security by not investing or not operating generation plants. The energy companies would, of course, need to adhere to the contractual obligation to their customers, therefore, it can be considered that the energy companies have little or no role to play in ensuring energy security.

12.3.4 Consumer's Role in Energy Security

At present, consumers have very little influence on energy security or the electricity supply industry as a whole. For industry, business and householders there are tariff mechanisms which aid in balancing supply and demand, however, they are fairly passive at present and are controlled by the utility companies. Tariffs include interruptible contracts for large consumers or multi rate tariffs, such as economy 7, for domestic users. Interruptible contracts are agreements with the System Operator in which the consumers get a reduction in the levies charged to use the system or a reduction in the overall energy bill for limiting the amount of energy they use when the capacity margins are tight. Multi rate tariffs work by offering the consumer cheaper electricity at night but more expensive rates during the day (in comparison to a standard tariff).

The introduction of a decentralised electricity system may see a drastic change as more consumers become stakeholders in the electricity generation industry. This would occur by firstly, engaging consumers with the electricity system through the location of the plant and its closeness to use, which can be considered a voluntary engagement. Secondly, an increased connection by becoming an energy actor and owning assets in the generation of electricity, which can be considered voluntary engagement. Thirdly, through demand management, which can be considered 'linked' to a decentralised system in order to balance out the any variable sources of generation. Mechanisms will need to incentivise demand management to a greater extent. This in turn will help to develop the necessary technology and to engage businesses, industry and householders in a more active role in modifying demand patterns. Involvement can occur through the 'time of day' pricing which allows consumers to react to changes in the price of electricity throughout the day.

In addition to this there would need to be effective development of Demand Management technology including meters for the consumer to identify the cost of electricity during the day and automatic response devices for air conditioning, refrigeration and any device which has the ability to be switched on and off according to the price of electricity without causing a major impact on the user.

Each of these different forms of engagement identify that it is possible for the consumers to become more involved in the energy system. Currently, security of supply is seen in terms of generation following demand patterns. If generation capacity fails to meet demand then supply security is compromised. However, the consumer group as a network of actors has the largest number of players, therefore, it has a profound ability to change the electricity system and shape its future. Consequently, the electricity system would need to see demand and generation as equal assets in the delivery of energy security in the electricity system.

The greatest change to the governance of the electricity system resulting from decentralised electricity may not be the increase in small-scale generation but the introduction of more stakeholders into the electricity supply industry. These would range from individuals householders and communities to small energy companies. An increase in the introduction of smaller stakeholders will not only come from decentralised electricity generation but also through the increased engagement with demand side response and smarter networks designed to increase flexibility of the system.

A small number of research participants discussed the idea of not only engaging the energy consumer, but also delivering technologies such as smart meters as having possible negative impacts. Interviewee 12 identified such changes as being more costly to the electricity system. Thus having an adverse affect on energy security. However, they were not discussed in terms of the benefits an engaged consumer can bring to the energy system. Further to this, there was a lack of discussion over the impact of a prosumer movement as discussed in section 2.11.1. The prosumer movement is driven by the ability for a consumer to produce their own power. The prosumer movement is also beginning to change the way in which consumers view the electricity system and change their roles and responsibilities.

This also leads to another theme, the use of the consumer in energy security. The literature and the perception of stakeholders imply that consumers have little or no role in energy security. A reason for this may be that energy security is seen solely in terms of supply meeting demand, however, the electricity system needs to be viewed as a two-pronged arrangement where demand can also be modified to meet supply through demand management technologies and operations. What is required is to employ the consumer's demand as a mechanism contributing to energy security. Equally, consumers who become stakeholders, either individually or within community projects, will become more active in contributing to a secure energy system.

However, a research participant (interviewee 18) did suggest a consumer who is engaged in the electricity system should have to take on the risk of their lights going out. One response to this is to say that if the lights go out, then energy security has failed.

12.4 What are the implications for the governance of energy security in a decentralised electricity future.

This thesis has argues the changes to governance which a decentralised electricity system would bring to energy security. One aspect which is clear is that there needs to be strong direction provided by Government for the future low carbon electricity system, whether this is centralised or decentralised. On top of this the definition of energy security used by Government needs to go further than simply quantifiable aspects and security of supply. This would mean the benefits of a decentralised electricity system are viewed in a more positive light. In addition to this it needs to be viewed as a longer term goal. The research participants identified the short term costs as a barrier to the decentralised electricity. However, the longer term benefits from its flexibility and diversity could have the ability to outweigh these costs.

The issue here is that asking consumers or business what they would be willing to pay in order to move to a low carbon decentralised electricity system may not take in to account then longer term savings and benefits.

Therefore, for the transition to low carbon decentralised electricity system to occur it would need to be driven by a development in the primary understanding of energy security alongside decentralised electivity currently being viewed as environmentally and socially better.

12.5 Recommendations for policy

The implications for policy for this thesis have been set out in two parts: the markets and the regulation. The two main governance tools of the electricity system can be argued to be these two aspects.

12.5.1 Markets and Incentives

The current market operation was set up with a centralised system in mind and therefore is dominated by a centralised process. The concern is that this operation can penalise some forms of decentralised electricity generation by 'locking out' smaller scale technologies.

The Electricity Market Reform is intended to establish mechanisms to replace and upgrade the UK's infrastructure by incentivising a further £110bn worth of investment (DECC, 2012n). However, the perception from the research participants is that the EMR is less of a reform and more a stimulus for minor adaptations to the current electricity market approach. A low carbon future will likely require a major change to the operation of the electricity system including the market system to allow more low carbon generation to enter. Nevertheless, there is an argument to say that a complete overhaul would require a trialling phase. Trialling new market arrangements would require time to analyse the effects on the generation system.

There is a strong argument to suggest that the EMR with the carbon floor price is a direct promotion of nuclear generation, thereby possibly undermining investment into small-scale generation. At present the small-scale electricity generation is supported through the FIT, in order for the small-scale generation to enter into the wholesale markets on a large scale there will need to be changes to current and reformed market operations. The issue with the current wholesale market is the dominance of the volatile price fossil fuels which thereby dictate the price of electricity.

It has been suggested that the level of competition in the wholesale market would be increased in a system of decentralised electricity (shown by Interviewee 1, 5, 6 and 27) as long as small-scale generation entered in the market place. A major change would be requires to the recent market reforms in order to allow small-scale generation to be introduced alongside the large scale generation. Large and small-scale technologies should be seen as complimentary technologies. The second option is for the small-scale generators to be supported by a separate mechanism similar to the current FIT. A mechanism such as FIT requires that small-scale generation are provided with a separate support mechanism, compared with, for example, nuclear generation. The small-scale support mechanisms should be easier to develop and understand and so be more open to a wider public. However, these mechanisms frequently require the intervention of a third party (often the Government) to set out the price paid for energy for each technology. In this way Government would be picking winners rather than allowing the emergence of the most effective technology. The third option is to have a completely separate market for small-scale generation. This market would be designed to provide a competitive framework for the small-scale generation and not conflict with any centralised generation already in place. It could also have the ability to develop the technologies through competition rather than through external subsidies.

12.5.2 Regulation

The second process of governance of the electricity system is through regulation. The transmission and distribution networks are natural monopolies and therefore require outside monitoring to ensure they meet the rules set out by Government.

The perception of the research participants was that as the networks were designed from a centralised perspective. Regulation reflects this centralised ethos and there would be a strong requirement for change to meet a decentralised electricity system.

One of the main changes from a centralised to decentralised system is that an increase in generation on the distribution network means the DNO's will need greater investment in their networks which is controlled by Ofgem. This needs to happen for two reasons: firstly, in order to ensure that the new generation is able to access the grid at multiple locations. Secondly, DNOs will become more active and possibly become system operators of each network area. Effective control of each area will require greater levels of information of activity on the network and the development of skills and knowledge base in order to operate an active network.

In order to achieve these objectives, changes will need to be made to the regulatory structure. These changes can be achieved in two ways, firstly, through the use of the price controls discussed in section 2.3. The price controls will need to allow the networks to meet the requirements of a decentralised electricity system by a forward looking approach to system constraints in order to increase the ability for connection to the grid. The second approach it to use specific incentives to fund specific projects. The incentives will need to be intelligently formatted to ensure the uptake in projects is adequate to provide sufficient generating capacity.

12.6 Further Research

12.6.1 Examining the changes to regulation in a decentralised electricity system

During the process of this research it was identified by a government-based stakeholder that they would not be sure if they could regulate a decentralised electricity system:

> *"do we have the skills to regulate a very decentralised system" Interviewee 22.*

Therefore it will be worthwhile examining what changes to regulation and the regulator will need to occur to ensure a secure decentralised electricity future. This will mean understanding how the decentralised system will impact on other scenarios such as the activity of the networks, the System Operator and the energy companies.

12.6.2 Differences in an international non-UK based electricity system

This thesis has specifically concentrated on the GB electricity system and the UK policies for governing such a system. A point for further research is to examine how these governance of energy security is achieved outside the UK and identify whether the same response to a decentralised electricity system is achieved. This would obviously broaden the scope of this research and require a much wider scale of investigation. However, it may be helpful to compare the results to different countries with different organisational frameworks such as an are which is controlled more by the state.

12.6.3 An energy system overview

In order to tighten the scope of this thesis the research was focussed on the electricity system. Therefore it would be beneficial to develop an understanding of how a decentralised electricity system would impact on the energy system as a whole. The issue with this is that even when focussing on a decentralised energy system the possible future scenarios can be wide, including different technologies, networks and actors. These issues would need to be established at the beginning.

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Annex A

Questions to Research Participants:

- What do you see are the current threats to energy security?
- In your opinion what are the main impacts of electricity decentralisation on energy security?
- Do you think decentralisation will affect investment patterns thereby negatively or positively affecting energy security?
- Would electricity decentralisation affect the current knowledge and skills base we have?
- Matching electricity supply and demand is a constant issue for network operators. Would a highly decentralised energy system make this easier or more difficult thus having an effect on energy security?
- Would a decentralised electricity system impact on the current electricity market arrangements?
- Are there risks to making the energy system more accessible to consumers?
- Who is responsible for ensuring energy security and how may this change in a system dominated by decentralised electricity generation
- Other issues you wish to raise?