DEVELOPING VIABLE SELF-SUSTAINING COMMUNITY-OWNED SOLAR PV PROJECTS IN THE UK THROUGH BUSINESS MODEL INNOVATION

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DEDICATION

I would like to gratefully dedicate this doctorate thesis to memory of my beloved father.

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DECLARATION

I declare that this document is my own work and that where any material could be construed as work of others; it is fully cited and referenced.

The research described in this thesis is the original work of the author except where otherwise specified or acknowledgement is made by reference.

It was carried out at the School of Built Environment, London South Bank University and under the supervision of Prof Andy Ford, Ass. Prof Deborah Andrews and Prof G.G. Maidment.

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ABSTRACT

The UK's energy system is predominantly centralised with a significant reliance on fossil fuels. The trilemma of successfully delivering energy security, equity, and environmental sustainability while dealing with an ageing energy infrastructure demands evolutionary changes within the entire energy system. In recent years the future of the UK's energy system has attracted growing involvement by local and community-based projects for energy generation, these involvements have begun to play an increasing role in the evolution of the UK's energy system. However, the development of these projects faces huge financial challenge due to a lack of consistent income stream and a viable business model.

The primary aim of this research is to evaluate ways to accelerate the formation and growth of Community Renewable Energy (CRE) initiatives in the UK by optimising existing community renewable energy model and developing an innovative business model that community-owned solar PV projects can take to progress under the post-subsidy conditions.

This project employed the mixed method approach including primary data collection (survey, semi-structured interviews), and the secondary data collection (desk-based literature review and reviewing Government and official reports) also, it uses the System Advisory Model as a simulation tool and business model Canvas as an analytical framework to address its aim and objectives.

This research has shown that UK's community-based energy sector has evolved rapidly since 2008 and has seen considerable growth in 2014. The business models used by community energy projects mostly depend on grants and public subsidies. Therefore, these projects have faced substantial financial challenges since January

2016 with the reduction in public subsidies for renewable energy (e.g. Feed-In-Tariff). The Feed-In-Tariff (FIT) scheme was introduced in the UK on 1st April 2010, with the aim of supporting small-scale (<5MW) renewable electricity generation. This study has shown these reductions caused the failure of many community-based renewable energy projects particularly solar PV projects.

This study critically investigated how the new CRE projects can be structured and developed to be financially viable when the FIT scheme is no longer available. Also, it further explores how the integration of solar PV and electricity storage can be structured to provide demand-side response services as well as, be a feasible and financially viable model for distributed energy system and community-owned solar PV projects in the post-subsidy condition.

The outcomes of this research is a developed and robust innovative business model to support the development of community-owned solar projects in the UK. Under the innovative model, these projects could become financially viable without the FIT, which the model can be extended to all community-owned solar projects in all localities.

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NOMENCLATURE

Symbols	Description
$\boldsymbol{C_0}$	Total initial investment cost at year 0
C_n	After tax cash flow
d_{real}	Refers to the discount rate without the inflation rate
$d_{nominal}$	Refers to the discount rate with the inflation rate
N	Analysis period and lifetime of project
Q_n	Electricity generated by the system in year n
Z_n	The annual project costs including; installation, operation and maintenance, financial costs and fees
n	Number of years analysed

LIST OF ABBREVIATIONS

AD	Anaerobic Digestion
BHA	British Hydro Power
BM	Business Model
BEIS	Business, Energy Industrial Strategy
CE	Community Energy
CRE	Community Renewable Energy
CAFE	Community Action For Energy
CBS	Community Benefit Society
Co-op	Co-operative
CIC	Community Interest Companies
CARES	Community and Renewable Energy Scheme
Capex	Capital expenditure
CEO	Chief Executive officer
CS	Co-operative Societies
CRI	Community Renewable Initiative
CPUC	California Public Utilities Commission
DTI	Department the Trade and Industry
DEFRA	Department For Environment and Rural Affairs
DNO	Distribution Network Operator
DSM	Demand Side Management
DSR	Demand Side Response
DNI	Direct Normal Irradiation
DHI	Diffuse Horizontal Irradiance
DUoS	Distribution Use of System
DECC	Department of Energy and Climate Change
DG	Distributed Generation
EIS	Enterprise Investment Scheme
ESCo	Energy Services Company
EE	Energy Efficiency
FCA	Financial Conduct Authority
FIT	Feed-in-Tariff
FFR	Firm Frequency Response
FCDM	Frequency Control Demand Management
GW	Gigawatts
GLA	Greater London Authority
GHG	Greenhouse Gas
IRR	Internal Rate of Return
JV	Joint Venture
kW	kilo Watt
kWh	kilo Watt-hour

LCBP	Low Carbon Building Programme
LCCC	Low Carbon Communities Challenge
LCOE	Levelised Cost Of Electricity
LEAF	Local Energy Assessment Fund
LCBP	Low Carbon Building Programme
LCA	Life Cycle Assessment
LLP	Limited Liability Partnership
MLP	Multi-level Perspective
MW	Mega Watt
NPV	NPV
NMC	Nickel Manganese Cabolatoxide
NREL	National Renewable Energy Laboratory
NGO	Non-Governmental Organisation
NIMBY	Not In My Back Yard
Ofgem	Office of Gas and Electricity Markets
PPA	Power Purchase Agreement
PV	Photovoltaics
RE	Renewable Energy
REA	Renewable Energy Association
RHI	Renewable Heat Incentive
RCEF	Rural Community Energy Fund
REIF	Renewable Energy Investment Fund
RO	Renewable Obligation
REIF	Renewable Energy Investment Fund
RET	Renewable Energy Technology
R&D	Research and Development
SSE	Scottish Energy Company
SEIS	Seed Enterprise Investment Scheme
STOR	Short Term Operating Reserve
SAM	System Advisor Model
SITR	Social Investment Tax Relief
SNM	Strategic Niche Management
TOUT	Time Of Use Of Tariff
TOU PPA	Time Of Use Of Power Purchase Agreement
TNUoS	Transmission Use of System
TNO	Transmission Network Operator
TPES	Total Primary Energy Supply
TPLS	Third-Party Licensed Supplier
UCEF	Urban Community Energy Fund
UKERC	UK Energy Research Centre

CHAPTER 1 INTRODUCTION

1.1 Background

The UK's energy system is largely centralised with a major reliance on fossil fuels and there is a trilemma of successfully delivering energy security, equity, and environmental sustainability whilst dealing with an ageing energy infrastructure demands evolutionary changes within the entire energy system.

In order to meet the UK's national binding target of an 80% reduction in carbon emissions by 2050, and the Renewable Energy Directive target which aims for 15% of the total energy consumption to come from renewable energy (RE) sources by 2020, the large-scale deployment of decentralised energy systems will be required in the UK (International Energy Agency, 2012).

The transition towards RE and decentralised energy systems can occur simultaneously with the shift away from governance of corporate utility, towards a more diverse mix of community and citizen investors being involved in the generation of RE (Hall and Roelich, 2015). For example, the transition that occurred in Denmark was largely successful due to strong institutional and public support for community ownership of RE generation. Denmark's energy system transitioned from being 99% dependent on imported fossil fuels in 1970 to becoming a net exporter of natural gas and electricity (Sovacool et al., 2008). 23% of Denmark's wind capacity is co-operatively owned by community and citizen investors, with around 100,000 individuals owning over 3,200 turbines (Bolinger 2001; Haggett, et al., 2014). Similarly, in Germany, the transition towards a focus on RE, or 'energiewende', occurred as a result of support from communities and citizen investors. 46% of the total installed RE capacity in Germany is owned by the citizen, and 41.5% is owned by institutions , the contribution from energy suppliers only amounts to 12.5% (Haggett et al. 2014).

The potential advantages of a more localised pattern of energy production and the involvement of local communities in renewables development in the UK first appeared in the late 1990s (Walker et al., 2007). However, in comparison with other European countries such as Germany and Denmark, renewable technology was not appreciated as an industrial opportunity by policy-makers in the UK (Helm, 2005). Consequently, very little policy was formulated to support RE at this time.

Nevertheless, in recent years the participation of communities and individuals in energy production and sustainable development has been a significant part of the UK's Government approach towards a low carbon future. One of the key points in the previous UK Government Low Carbon Transition Plan on National Strategy for Climate Change and Energy, published in 2009, was to support communities in their efforts to tackle climate change and to provide opportunities for them to develop innovative ideas and make knowledgeable decisions surrounding sustainable growth (HM Government, 2009).

Community Renewable Energy (CRE) projects which aim to create more sustainable energy systems are an example of 'Community Innovation,' which refers to a form of bottom-up or 'grass-roots' innovation brought about by communities rather than the Government or businesses (Tang et al., 2011). This innovation provides several key benefits for sustainable development which conventional or 'top-down' measures could not. These projects often have wider impact on local communities, as they can directly relate sustainability challenges to individuals and their lives, much more so than a government-sponsored campaign can (Seyfang and Smith, 2007). Grass-roots innovation projects provide an opportunity for social good to be taken into consideration in the journey towards a renewable and sustainable future (Seyfang and Smith, 2007).

On 27th January 2014, the UK Government published the first ever Community Energy Strategy (DECC, 2014b) and highlighted the effectiveness of community-led action in tackling the challenges facing the UK energy system (DECC, 2014b). The Strategy explicitly stated that community-led action:

'*can often tackle challenges more effectively than Government alone, developing solutions to meet local needs, and involving local people'* (DECC, 2014b pp.7).

With the help of recent policies, CRE projects have begun to play an increasing role in the evolution of the UK's energy system. However, this development is occurring at a much slower pace compared to other EU countries such as Germany and Denmark, with CRE projects only contributing to only 0.4% of total UK RE installation (Seyfang et al. , 2013; DECC, 2014a; Haggett et al., 2014; Harnmeijer, 2016). The development of the UK's CRE initiative is facing several challenges: these challenges are not usually related to technological issues, as the technology has proven to be effective internationally, but instead it is domestic issues which pose a challenge, particularly those involving funding and institutionalisation.

The UK Government attempted to create viable income streams for CRE groups by introducing new energy policy measures such as the Feed-in-Tariff (FIT) and Renewable Heat Incentive (RHI). Co-operative ownership schemes are now emerging and have been successful. Despite this, their progress has been relatively slow compared to other European countries, and the question is posed as to how rapidly they can be diffused in the UK (Walker, 2008).

The FIT scheme has increased the financial viability of CRE projects (Cherrington et al., 2013; Nolden, 2013a). However, one crucial concern for the UK's current CRE initiatives is to shape a consistent income stream specifically for projects established after the major reduction to FIT that occurred in 2015. Although most of the established community energy organisations in the UK have a viable business model in place, these mostly depend on grants and public subsidies which are not a reliable source of income as they are often only available for the short-term (Walker et al., 2007; Hielscher, 2011). The major reduction in FIT have made it very difficult for established groups, and virtually impossible for groups that are not yet established. Consequently, the UK's CRE sector faces new challenges and must now consider alternative business models to ensure the economic viability of its projects.

This PhD thesis analyses the role of the business model, as well as socio-technical factors, in the development of the UK CRE sector, before and after the curtailment of RE support mechanisms. Specifically, it focuses on ways to accelerate the formation and growth of CRE initiatives in the UK by developing an innovative business model approach that CRE groups can take to progress under new policy conditions (without subsidies). It investigates how an innovative business model such as combining electricity storage and demand side response, can overcome the challenges facing the development of these projects due to the major reduction of the FIT generation rate.

The desired outcome is a developed, validated and robust and innovative business model to support the development of CRE and a distributed energy system in the UK. In order to address the aim and objectives of this study, a mixed methodology approach has been taken, including primary data collection by way of surveys, semi-structured interviews and, secondary data collection from existing literature and official Government reports. Also, it uses the System Advisory Model as a simulation tool and the business model Canvas as an analytical framework.

This research contributes to industrial practices, knowledge and policy as it designed a novel and validated a business model to facilitate finance and operation and UK's community-owned solar PV in the post-subsidy condition. The developed model enables community and citizen investors to be involved in the generation of RE and grid balancing services even when grants and subsidies are not available.

1.2 Defining Community Renewable Energy (CRE) Projects in the Research Context

Community energy projects can cover a wide range of activities which include reducing energy consumption, energy demand management, RE production, collectively purchasing energy, and collectively switching suppliers. This thesis predominantly concentrates on CRE projects focussing on increasing the production of RE and reducing community energy dependency in the UK.

In the literature, the community-owned business model is described as a new way of promoting RE (Asmus, 2008; Huijben and Verbong, 2013); they are new in the sense that they are established and developed by the community instead of a public utility.

The existing literature categorises CRE groups as two types of communities: communities of locality and communities of interests (Bolinger, 2001; Stamford, 2004). Communities of locality are people in particular geographical areas while communities of interest are involved individuals living in different areas but sharing a common interest for example, to promote the development of RE (Bolinger, 2001). CRE projects are very diverse and can often be interpreted in numerous ways by policy-makers, academics and intermediaries, based on their degree of community involvement (Seyfang et al., 2013; Hielscher,2011; Rogers et al., 2008; Walker & Devine-Wright, 2008).

Undoubtedly the combination of the two words 'community' and 'renewables' in policy poses a fundamental question: what makes community energy projects different to other RE projects?

As shown in Figure 1, Walker & Devine-Wright (2008) answer this question by arguing that CRE projects involve two dimensions of 'process' and 'outcome,' a process dimension focusing on who projects are developed and run by, and an outcome dimension focusing on how the results of projects are spatially and socially distributed; in other words, who gets what? (Walker and Devine-Wright, 2008).

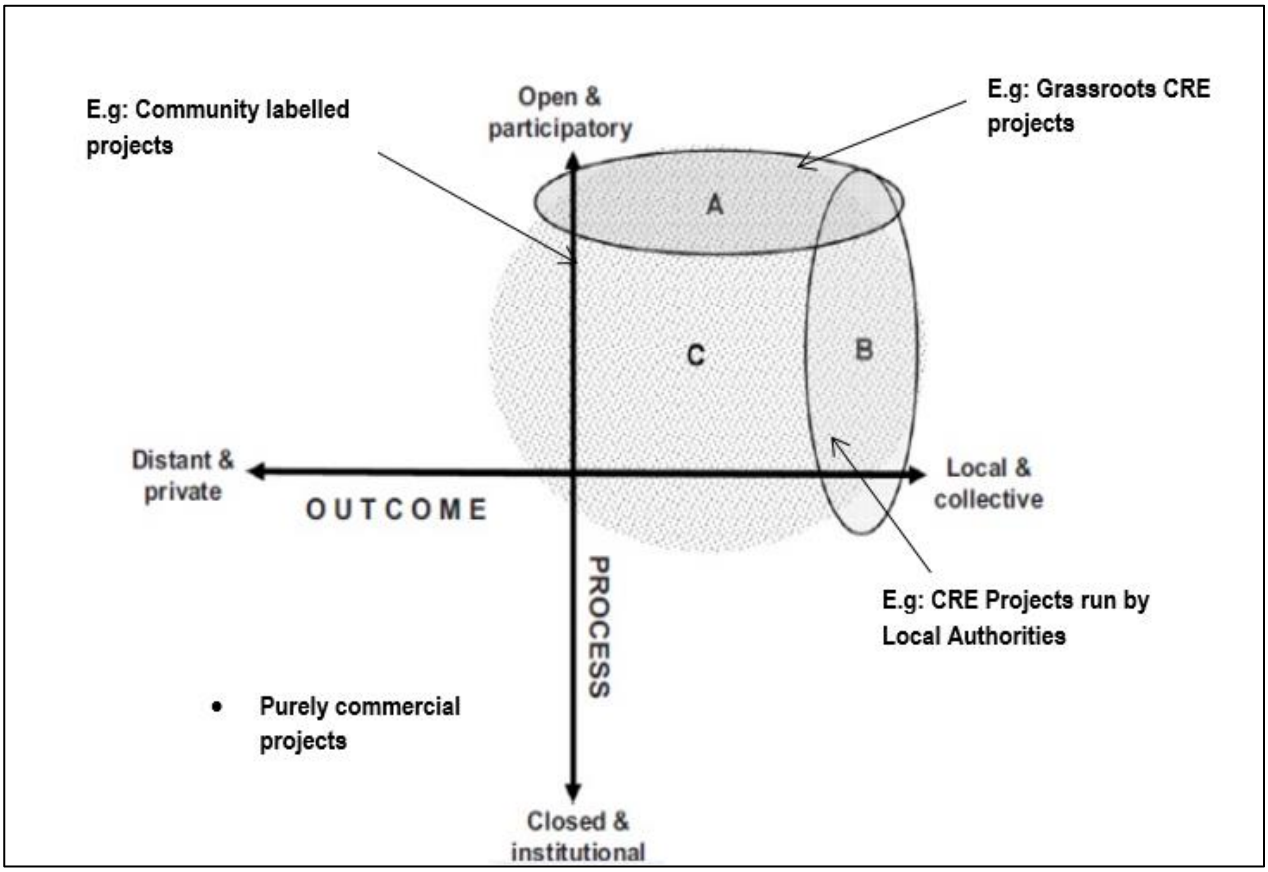

Figure 1. Understanding Community Renewable Energy in Relation to Process and Outcome Dimensions (Walker & Devine-Wright, 2008)

For the purpose of this thesis we follow the definition of CRE as proposed by Seyfang et al. (2013) and originally Walker & Devine-Wright: *'energy projects where communities (of place* *or interest) exhibit a high degree of ownership and control, as well as benefiting collectively from outcomes' (*Seyfang et al., 2013, pp. 978).

1.2.1 Research Questions and Aims

The primary aim of this research is to evaluate ways to accelerate the formation and growth of CRE initiatives in the UK by optimising the existing CRE model and developing an innovative business model that community solar PV projects can take to progress under the post-subsidy conditions addressing the following research questions and objectives:

1.2.1.1 Research Questions

1. Why has the progress of the community energy sector in the UK been so limited, despite the support mechanisms that have been in place?
2. What role does the business model play in the transition towards a more decentralised energy system?
3. As the FIT is the primary source of revenue for many operating CRE projects how new CRE projects can be structured and developed to be financially viable when FIT is no longer available?
4. Whether and how in the post-subsidy condition the integration of solar PV and electricity storage can be structured to become a feasible and financially viable model for distributed energy system and community-owned solar PV projects?

1.2.1.2 Research Objectives

1. To critically evaluate the policy, strategy and existing literature on UK CRE projects to identify the factors that have an influence on the slow growth of the CRE sector.
2. Identify and evaluate emerging alternative business models, taking into account the available resources and financial risks or benefits.

3. Establish a database of existing CRE projects and their activities to provide in-depth assessment of alternative and innovative business models by exploring fundamental aspects of their business model structure.

4. Evaluate the key economic and socio-technical factors that contribute to the success of the CRE sector, and identify the perceived challenges faced during their future development.

5. Evaluate the impact of the curtailment of RE support mechanisms in 2015 on the development of the UK's CRE sector and identify the perceived challenges facing their future development.

6. Run techno-economic analyses to investigate, whether the integration of solar PV and electricity storage can be structured to provide demand-side response services, enabling peak shaving and electricity balancing services and in turn, create a feasible and financially viable model for community-owned solar PV projects in the post-subsidy condition.

7. Use the System Advisor model developed by NREL as a simulation tool to develop and validate a business model for community-owned solar projects, the most common types of existing CRE projects under the new policy conditions.

1.3 Thesis Structure

Chapter 1 gives the introduction to the scope of this study as well as outlines the aim and objective of this project.

Chapter 2 presents a critical analysis and evaluation of existing literature and theory. This chapter is split into four parts. The first part, gives an introduction to the UK's energy system and energy market. The second part critically reviews the role of CRE projects and community innovation in the energy transition through theoretical frameworks, and concepts such as ‘grass-roots’ innovation, the socio-technical system and the business model. The third part critically evaluates existing CRE projects in the UK and goes further to compare the development of the sector in the UK to that of other European countries, specifically Germany and Denmark. The final part evaluates the literature on both established and innovative business models, to provide insight into the role of the economically and environmentally sustainable business model in the transition towards a decentralised energy system.

Chapter 3 provides an overview of the methodology employed in this thesis. It begins by outlining the focus and potential scope of the research, followed by the strategy and methodological approaches taken to address the research questions. Details of the survey and semi-structured interviews used are outlined, along with the System Advisor model software. Three analysis chapters follow the methodology section, which are based on the objectives presented in the introductory chapter.

Chapter 4 presents the empirical findings from an independent survey and semi-structured interviews. This chapter critically evaluates the business structures of existing CRE projects (between 1999 and 2016), particularly analysing each of their business models. The chapter goes further to critically analyse the success of CRE projects and assess the perceived challenges facing their development between 1999 and 2016.

Chapter 5 presents the key findings from the second part of the survey and the semi-structured interviews which aimed to evaluate the impact of RE support mechanism curtailment in the UK. The chapter then investigates cases of promising business models, based on the available resources and current UK regulations.

Chapter 6 investigates the financial viability of combining electricity storage and solar PV in order to provide demand side response and to form a practical model for community-owned solar PV projects in post-subsidy conditions. This chapter explores the results from the simulation tool, which was used to investigate and analyse feasibility of integrating solar PV and electricity storage in non-domestic buildings.

In chapter 7, various key findings are emphasised in relation to the original aims and objectives. The chapter concludes by highlighting how this thesis offers an original contribution to knowledge and outlines where further exploration is required due to the scalar limitations of this study.

CHAPTER 2 CRITICAL LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to provide a critical review of the existing academic and policy literature on UK's Energy system and CRE projects. This chapter encompasses four main parts; the first part, gives an introduction to the UK's energy system and energy market.

In the second part of the chapter, the role of CRE projects and community innovation in the energy transition are critically reviewed using the different theoretical frameworks, including the concepts of grass-roots innovation, socio-technical systems, and business models.

The third part of the chapter critically evaluates existing CRE projects in the UK in order to gain a profound understanding of their characteristics. Additionally, this chapter compares the development of the UK's CRE projects to those in Europe, particularly in Germany and Denmark, exploring the factors which have been fundamental to the growth of European projects, and therefore highlighting the shortcomings of UK projects.

In fourth part of the chapter, the literature on both established and innovative business models is reviewed, shedding light on the role of the economically and environmentally sustainable business model in the transition towards a decentralised energy system.

2.2 Overview of the Global Energy System

The global demand for electricity is increasing rapidly, in order to keep up with this growth and to replace existing power plants that are reaching the end of their operational periods by 2040, approximately 7200 GW of capacity must be built (International Energy Agency, 2013). Although the world has a vast supply of fossil fuels, the percentage that can economically be extracted is limited (Everett et al., 2012), and the production rates of many resources are limited by the unavailability of financial investment as well as political uncertainty. Therefore, the supply of fossil fuels may be inadequate to meet the world's current levels of energy demand (Everett et al., 2012). Nuclear power, which plays a key role in energy security for some countries, faces an unstable future due to radiation hazards and public opposition (International Energy Agency, 2013). Furthermore, to tackle climate change issues and to achieve the Paris agreement target, which aims to keep the planet's average air temperature below the 2 °C limit, the world requires to accomplish a radical reversal in world's consumption of energy resources and in current GHG (United Nations Foundation, 2015).

In recent years, there have been significant changes in the world's consumption of energy resources and growth in the RE market. Despite this growth, the majority of the world's primary energy sources are from fossil fuels, with oil representing 36% of global energy consumption. Natural gas accounts for 26.9% and coal 17.1% of the total power generated globally. The rate of transition towards low carbon and RE is much lower than required to achieve the current carbon emission targets (International Energy Agency, 2017; Everett et al., 2012), as public opposition to the development of energy resources continues to pose a challenge (International Energy Agency, 2016).

Meanwhile, energy system are decentralising, as the role of locally generated power has become more significant. The role of decentralisation is particularly important to rural and low-income populations which do not have access to electricity. The number of people in the world in this category remains dramatically high, at approximately 1.2 billion (International Energy Agengy, 2017). It is likely that around half of these people will gain access to electricity either from a decentralised energy system or solar generators, rather than a traditional centralised energy system in the future.

2.3 The Current State of the UK's Energy System

In 2015, the energy supply sector accounting for 29% (Figure 2.1) was the largest contributor to the UK's greenhouse gas emissions, with carbon dioxide (CO2) being the predominant emission from this sector. This result can be attributed to the UK's high dependency on coal and natural gas for electricity generation (Department of Business Energy and Industrial Strategy, 2017a).

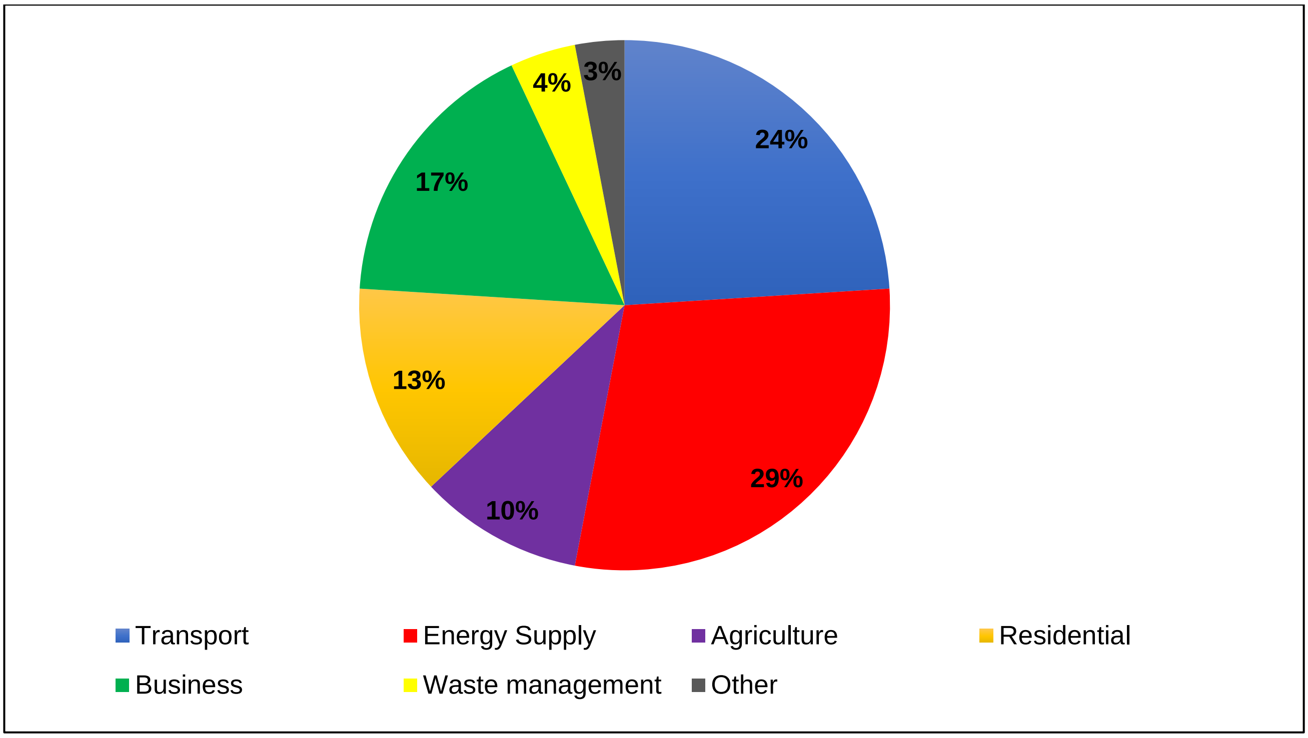

Figure 2.1 UK's Greenhouse Gas Emission By Sector, in 2015 (Department of Business Energy and Industrial Strategy, 2017a)

Recent progress has been made to reduce this dependency and in 2016 power generation from coal decreased by 13.2% and generation from gas increased by 12.9%, in comparison to 2015. However, the amount of power generated from RE sources fell by 0.2% over the same year, as indicated in Figure 2.2 (Department of Business Energy and Industrial Strategy, 2017b).

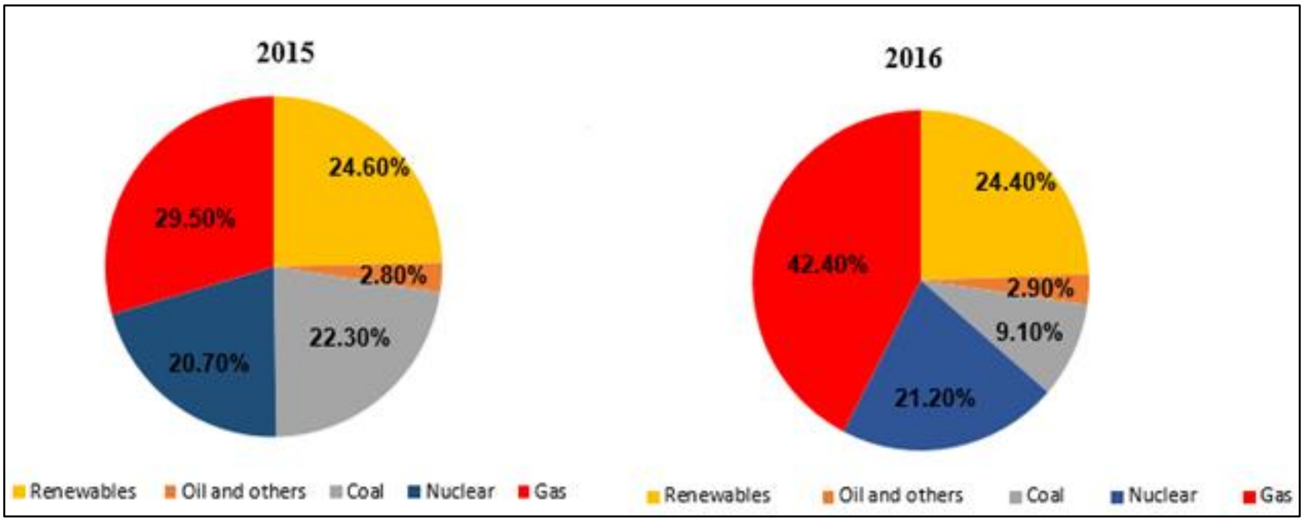

Figure 2.2 Source of Electricity Generated In 2015 and 2016 (Department of Business Energy and Industrial Strategy, 2017b)

2.3.1 Challenges Facing the UK's Energy System

To tackle both the problems of climate change and energy security, and to ensure sustainability, the UK's energy system must be transformed. A number of critical challenges faces the goal of creating a decarbonised, secure and affordable energy system in the UK The first challenge is how to ensure a reliable electricity supply whilst it is in the process of being decarbonised (International Energy Agency, 2012). Secondly, the affordability of the energy system is thrown into question as around a fifth of the UK's electricity generation capacity will be closed by 2025, including approximately 12 GW of coal and oil-fired capacity, and 7 GW of ageing nuclear power capacity(International Energy Agency, 2012). It is estimated that an investment of over £110 billion is required to build the equivalent of 20 large power stations and to upgrade the UK's electricity infrastructure (DECC, 2011). Another challenge is that the demand for electricity is predicted to double by 2050 as further transport and heating is loaded onto the electricity grid (DECC, 2011) particularly by the increasing use of electric vehicles.

The barriers that the UK will face in the future can be tackled by taking both a centralised and decentralised approach (Allen et al., 2012), but ultimately decentralised energy systems can overcome many risks and issues identified with the current centralised system. Furthermore, according to the national binding target established in the 2009/28/EC Directive, 15% of the UK's total energy consumption must come from renewable sources by 2020 (International Energy Agency, 2012). However, the main challenge posed by this target revolves around investment and planning risks (Nolden, 2013b).

Currently, about a third of the UK's primary energy is lost in the transmission and distribution system, predominantly in the form of waste heat from power stations (Boyle, 2012). These losses are higher than the total energy demand for space and water heating (Boyle, 2012). Additionally, without reform of the electricity market, the country would rely largely on one type of energy generation, causing huge security and affordability issues. As a result, the UK would be exposed to price instability and therefore be less able to achieve the climate change target.

2.3.2 The Challenges of Decarbonisation

The transformation of the UK's energy system is limited by an extensive range of challenges. Firstly, the infrastructure of the UK's energy system has a large degree of path dependency, meaning that the process of decarbonisation is conditioned by the historical pattern of energy generation within the country. As a consequence, significant political and economic changes are required in the UK, as otherwise new policy will be 'locked in' to existing technologies (Winskel et al., 2009). Secondly, decarbonisation of the energy system involves a long infrastructural replacement period. Simultaneously, existing energy systems tends to replace infrastructure on a 'like-for-like' basis, reducing diversity in investment patterns. Finally, using renewable technologies poses a financial and investment risk, as they are characterised by both high capital costs and low running costs (Nolden, 2013b). However, the cost of renewable energy technologies such as solar PV is decreasing steadily which would encourage the uptake solar PV.

2.3.3 The UK Energy Market

Following the liberalisation of energy markets, the both UK's generation and supply market became competitive, despite being dominated by the 'big six' (E.on, EDF, NPower, SSE, British Gas and Scottish Power), contradictorily making the energy market notoriously uncompetitive. The 'big six' serve approximately 95% of domestic electricity and 80% of commercial supply in the UK (Johnson and Hall, 2014). Although the generation market is predominantly controlled by the 'big six,' there are five additional suppliers, ESB, Drax, GDF Suez and AES, which collectively form the 'big ten' (Johnson, and Hall, 2014). Evidence indicates that the nature of the UK supply sector is changing. For example, at the end of January 2013, cumulative shares of the domestic energy market held by major suppliers fell below 95% (with at least 30 companies supplying energy), reaching the lowest level in history since the liberalisation of the energy market (Moss and Buckley, 2014).

Furthermore, with the CRE sector entering the supply market, a number of municipal companies have emerged, such as Robin Hood Energy (owned by Nottingham City Council) and Bristol Energy (owned by Bristol City Council), as well as there being plans in London to set up similar suppliers by the Mayor of London. This indicates that there is significant potential for local people and authorities to participate in the UK supply sector (Bristol Energy Cooperative, 2017; Hellier, 2015; The Guardian, 2016). In 2012 the dominant energy suppliers, known as the 'big ten' owned 85.2% of the UK's generation capacity. The remaining share (14.8%) was divided between 64 medium-sized private organisations and corporate bodies. The energy generated by the UK's 'big six' accounted for 47% of the country's RE capacity (Johnson, and Hall, 2014). RE currently has a much less established ownership structure, and valuable ownerships remain predominantly in private hands.

2.4 Theoretical Background: Socio-technical Transitions

The previous section has highlighted the importance of the transition towards RE and decentralisation for the UK's energy system. The following section will critically review the role of CRE projects and community innovations in the energy transition by using the different theoretical frameworks.

2.4.1 Defining Grass-roots Innovation

The aim of this section is to explore further the ways in which innovation can be brought about through local grass-roots initiatives and civil societies taking a bottom-up approach. CRE projects are an example of grass-roots innovation as they are developed by local communities rather than the Government or businesses. Innovation can be seen within many different aspects of these projects, for example, the fact that CRE groups are establishing and developing ways to provide energy to communities rather than through a public utility, and the different ways in which CRE projects can now be funded reflect new and inventive thinking (Martiskainen, 2014).

Seyfang and Smith (2007) have defined the term 'grass-roots innovation' as 'innovative networks of activists and organisations generating novel bottom-up solutions for sustainable development; solutions that respond to the local situation and the interests and values of the communities involved' (Seyfang and Smith, 2007, pp 585).

Smith et al. (2014) emphasise the fact that the people and organisations who are often activists for grass-roots innovation do not always come from local communities, but are engaged in the their ideas and developments. Some examples of grass-roots innovation within local communities are car-sharing groups, voluntary recycling schemes and projects promoting the sustainable development of energy (Seyfang and Smith, 2007). Many businesses which are brought about by grass-roots innovation fall within the bracket of ‘social enterprise’, organisations which use socially responsible business models for the benefit of the community. Furthermore, this type of innovation differs from that of the major business market because it is driven by social requirements and ideology, rather than commercial gains or profit-oriented goals (Seyfang and Smith 2007; Seyfang and Haxeltine, 2012).

The major hurdles encountered by grass-roots innovators are linked to the challenges of maintaining a viable, sustainable and socio-technical space within a wider unsustainable regime (Hielscher et al., 2010). This relates to various challenges surrounding secure funding, managing structural change and effectively networking, which ultimately can lead to the possibility of institutionalisation (Hielscher et al., 2010). Community-led innovation usually remains small-scale and more often than not fails to develop due to lack of institutional and long-term financial support (Seyfang and Haxeltine, 2012; Hielscher et al., 2010). It is unfortunately the case that grass-roots projects spend the majority of their existence attempting to effectively ‘survive’, and only a small amount of their time actually growing and developing (Seyfang and Smith, 2007).

2.4.2 Socio-technical Transition

Much of the existing research on the transition towards a more economically and environmentally sustainable energy system outlines a socio-technical approach, which provides a theoretical framework for the thesis. A transition requires a process of change to occur, which usually involves a structural transformation from a relatively stable state to a new one, through the co-evolution of markets, technologies, networks and policies, as well as individual behaviour. Energy transitions are often referred to as 'socio-technical' transitions, as they require the total rearrangement of a system which involves, technology, policy, markets, infrastructure, culture and consumer behaviour (Geels, 2011). Socio-technical transition is not limited to technological changes, but it can also involve other elements within a system such as regulations and structural practices (Bidmon and Knab, 2014).

This transition is a series of processes which lead to changes in the socio-technical system, predominantly the ways that key services, such as energy and transport, are provided in societies. According to Geels (2004), a socio-technical system is one which delivers fundamental services to a society such as energy, transport, healthcare and education, interlinking institutions, services, users and practices. Additionally, this type of system places emphasis on the role of different social groups which can be influential in the development and adaptation of technology (Geels, 2004).

According to Geels (2011), transitions towards sustainability involve the *'interaction between technology, policy/power/politics, economics/business/market and culture/discourse/public opinion'*. Therefore, a theoretical framework is required that addresses the multiple aspects of transition, as well as the dynamics of structural change (Geels, 2011). As a result, the multi-level perspective (MLP) on sustainability transitions has been developed. The MLP emphasises the mutual dependence of both social and technical elements within socio-technical transitions (Geels, 2002; Geels and Schot, 2007), which will be analysed in depth in the following section.

2.4.3 Multi-Level Perspective (MLP)

MLP was first established by Geels (2002), who outlined its three key elements: niches (micro-level); regimes (meso-level); and landscape (macro-level). All three levels are connected, providing an understanding of how new innovations can develop into niches, and subsequently how niches are diffused within a shifting regime (Martiskainen, 2014).

The micro-level innovations involve novel practices, new technologies, and emerging organisations and projects (Loorbach, 2007). According to Huijben & Verbong (2013), radical innovations and sustainable technologies can be developed in protected spaces called 'niches'. Niches are considered to be key elements within a transition because they stimulate and enable systemic change (Geels, 2011). In order for niches to develop, they require supporting regulatory structures (subsidies), as they are surrounded by a high degree of instability within the new socio-technical configuration, and a lack of sufficient market demand (Huijben & Verbong 2013). As argued by Schot & Geels (2008), niches are not introduced by Governments but instead they emerge through collective activities within communities.

The term 'regime' refers to a dominant market structure and the users, institutions and scientific knowledge which exist within it. A regime is a well-structured configuration of actors, institutions and technologies, which are often inflexible and act as barriers for innovation (Bolton and Hannon, 2016). The final 'landscape' level of the MLP involves macroeconomics, macro politics, and macro cultural factors, meaning that transformation at this stage usually take place very slowly.

Firstly, niche innovation develops as a result of internal drivers, increasing knowledge and support from powerful groups, and then transformed at landscape level. By putting pressure on the regime and eventually threatening its existence, this in turn creates opportunity for further niche innovation to occur (Figure 2.3) (Geels and Schot, 2007).

According to (Seyfang and Haxeltine, 2010), community energy projects in the UK reflect the theoretical framework of the MLP. In this particular case, the emerging niche innovation is extremely vulnerable and sensitive to changes in Government policy and support. Nevertheless, community energy is proving that it can act as the type of niche innovation that has the potential of dislocating and disrupting the current energy regime, transforming it into a more socially and environmentally aware system (Walker, 2015).

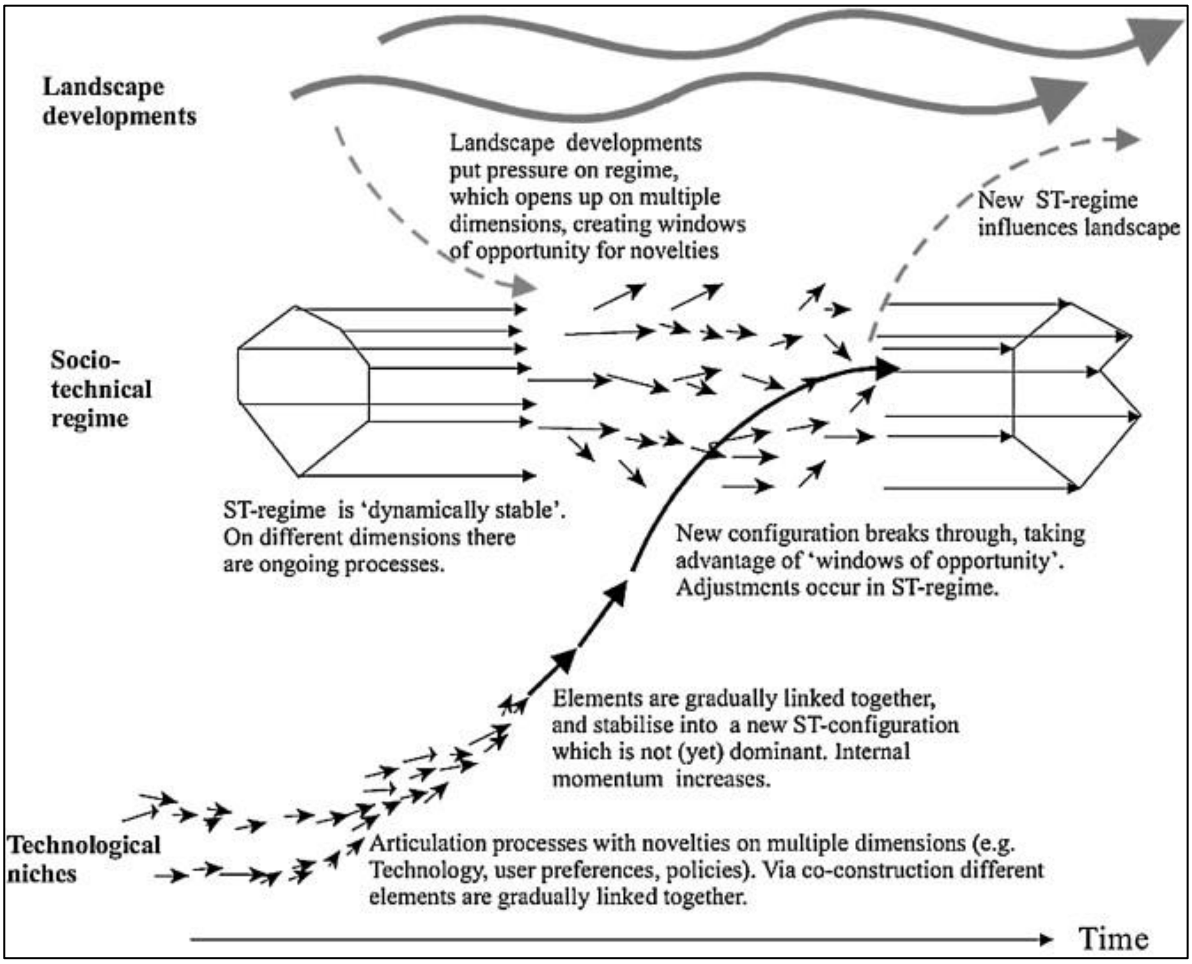

Figure 2.3 The Multi-level Perspective on Transitions;(Geels and Schot, 2007)

2.4.4 Strategic Niche Management (SNM)

Section 2.4.3 explored the MLP in energy transitions, which presented the concept of niches fitting within a much larger socio-technical system. This section goes further to examine Strategic Niche Management (SNM), which is covered widely in literature on energy transition. SNM focuses on socio-technical transition in particular, or the shifting of major societal functions (Huijben and Verbong, 2013). SNM was introduced as a way of bridging the so-called 'valley of death' between research and development (R&D) and to help new technologies emerge into the market (Schot and Geels, 2008). They argue that there is little consumer demand for many sustainable innovations, and that they are unpopular amongst the mass market, simply because they present a radical move away from existing technologies and systems in place. Therefore, SNM was developed in order to deliver a theoretical framework for the management of innovation which has a long-term social objective such as sustainability, and involves radical novelties which conflict with existing infrastructure, policy and practice (Schot and Geels, 2008).

Geels and Deuten (2006) have explored the way that niches start to develop from a socio-cognitive perspective. Their development takes the form of a non-linear process comprising of four different phases: a local phase; an inter-local phase; a trans-local phase; and a global phase (Figure 2.4).

During the first phase (local phase), new technologies emerge as a result of local practices and are often limited to only creating knowledge for the purpose of individual projects. The process of knowledge exchange is very gradual, and takes place largely through word of mouth (Geels and Deuten, 2006).

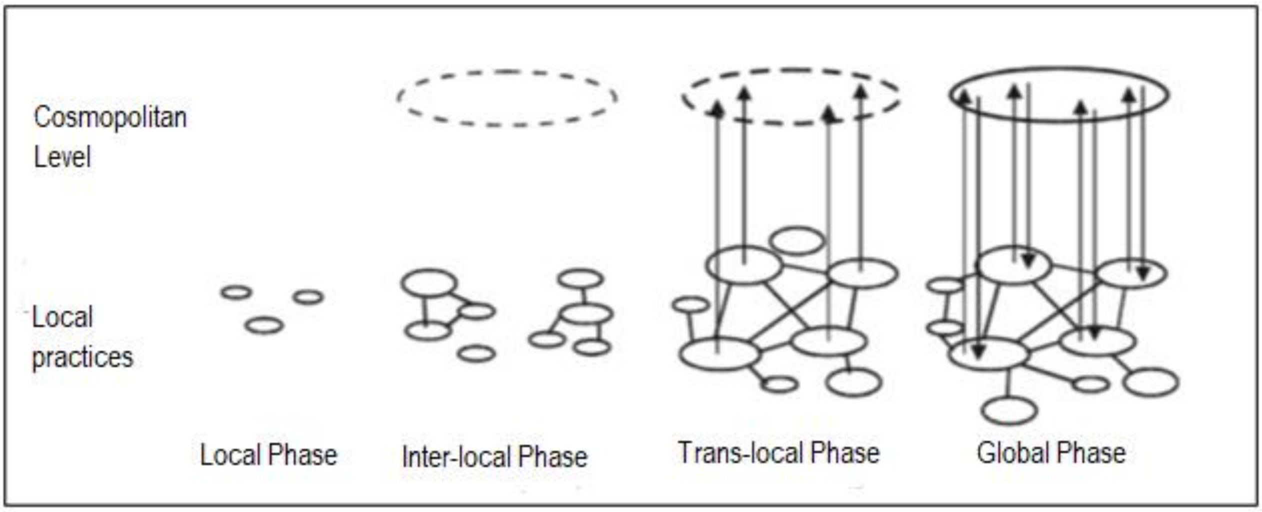

Figure 2.4 The Four Phases of Technological Knowledge Sharing; Geels and Deuten, 2006

The next inter-local phase involved the expansion of the knowledge space to a larger network, in which technical knowledge can be exchanged between groups. However, at this stage, knowledge often remains within the network and is rarely disclosed to external actors (Geels and Deuten, 2006). It is not until the third trans-local phase that knowledge exchange takes place in wider circulations, for example through the distribution of handbooks and articles. Another characteristic of this stage is the emergence of intermediary actors and infrastructures which enable the circulation of knowledge, for example through organised workshops and conferences (Geels and Deuten, 2006).

As niches move towards the final global phase, and begin to stabilise, they must become classed as ‘generic’ knowledge in order for them to be diffused into a wider market. The transition is fully complete once stabilisation occurs and consequently, knowledge becomes an established set of prominent rules which can be used as a guide for conducting local activities on a global scale (Geels and Deuten, 2006).

According to Seyfang et al. (2014), the UK’s community energy projects are currently in the inter-local phase, meaning that an emerging niche is manifest, but it is incoherent in terms of direction and neither robust nor influential. They argue that knowledge is exchanged between different CRE groups within the UK, rather than through dedicated networking and intermediary organisations. By applying the framework of SNM to the UK’s community energy sector, the need for more conducive policy is highlighted, particularly that which will help intermediary organisations to increase the circulation of knowledge and enable projects to diffuse on a global level (Seyfang et al., 2014).

2.4.5 The Business Model Concept

Since mid-1990, the concept of the business model has increasingly gained interest amongst both practitioners and academics (Huijben and Verbong, 2013). According to

Richter (2011), the business model can be understood as a structural framework that defines a firm's organisational and financial foundation. Bidmon & Knab (2014) argue that the business model can play a vital role in the stabilisation of technological innovation. They suggest that the implementation of a business model can create its own intermediary level between niche innovation and a socio-technical regime (Figure 2.3). The MLP theory suggests that the business model can help create a better structure for local activities, as opposed to the implementation of technology.

Osterwalder (2004) defines the business model as the means for an organisation to create and deliver value. However, there is no uniform definition of the business model within existing literature. Current literature provides various different definitions, but as seen in Figure 2.5 all include four fundamental aspects: value proposition; customer interface; infrastructure; and revenue model (Aslani and Mohaghar, 2013; Johnson and Suskewicz, 2009; Osterwalder, 2004; Richter, 2011).

Value proposition focuses on the economic return of a product or service offered by a firm (Bocken et al. 2014). The customer interface refers to the communication between a company and its target market, and the types of relationships that can be established with this particular customer segment.

The infrastructure aspect of the business model takes into consideration the ways that a firm can capture value and earn revenue through the services and goods it provides (Bocken et al., 2014). The final element, the revenue model, explores the potential income that can be generated from a business as well as the cost involved its operation.

The business model has been used widely as a tool to analyse and classify companies and their activities (Herbes et al., 2017; Richter, 2013). Osterwalder (2004) conceptualises to the business model as a Canvas (Figure 2.5), an idea which has been employed by researchers examining RE companies. For example, Aslani and Mohaghar (2013) and Richter (2011), classify RE business models on the basis of their key resources (types of renewable technology), and their key activities, such as generation, transmission and distribution.

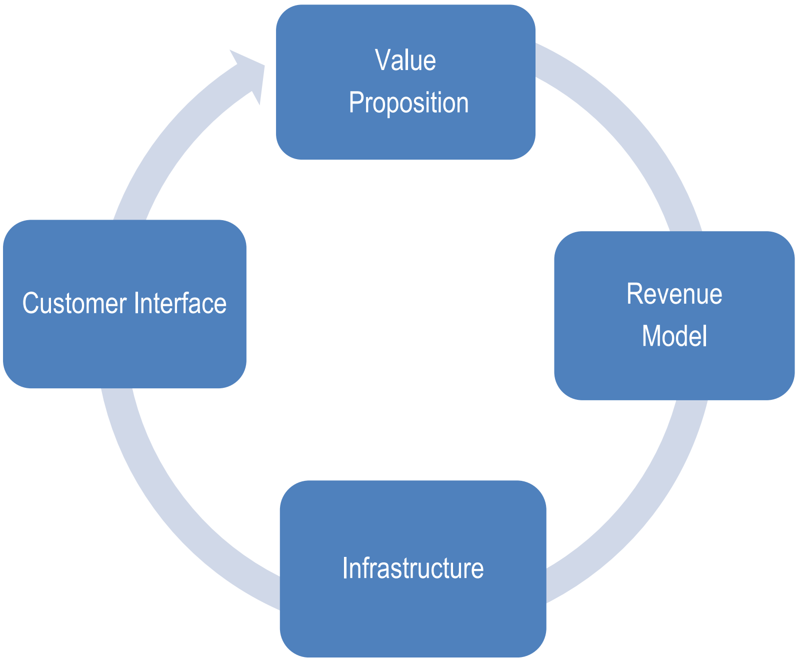

Figure 2.5 Conceptualisation of the Business Model (Osterwalder, 2004)

2.4.6 The Combination of the Business Model and Strategic Niche Management (SNM)

According to Huijben & Verbong (2013), by combining the concepts of the business model and SNM, a new perspective is created towards the development and scaling up of radical innovation. Business model mapping can be used to support this analysis, creating a typology of business models that are being experimented with. Moreover, SNM provides a greater understanding of the way in which business models operate, and how they tackle the wider barriers facing their acceleration (Huijben & Verbong 2013).

By combining these two concepts together, the importance of network structures is emphasised. However, they differ in the fact that the literature on business models usually focuses on a local network, while SNM takes into account the impact of a wider network, and its role as an enabler of knowledge and resource sharing.

2.5 Overview of the Development of the UK's CRE Sector

In recent years, local and community-led projects in the UK have become much more involved in energy generation. The development of community-led projects can play an important role in enhancing sustainability as it helps the country to achieve its environmental targets, providing both social and economic benefits, such as regional development, income diversification and reducing the cost of energy and fuel. The following sections will critically evaluate the role of political and socio-technical factors in the development of the UK's CRE sector.

2.5.1 Trends in Development of the UK's CRE Sector

Community-led energy projects have thrived in the UK with the help of recent policy measures supporting the transition to a low-carbon and RE system (Seyfang et al., 2013). CRE projects have grown from contributing < 0.01% in 2005 to just under 0.4% of the total UK's RE in 2016 (Harnmeijer, 2016). Currently, the CRE sector provides energy to the equivalent of 85,500 homes in the UK, with almost 188 MW of capacity being installed by community energy groups by 2017 (Community Energy England, 2017).

A web-based survey identified that there are over 500 CRE projects running in the UK (Seyfang et al., 2013). To date, community energy in the UK focusses predominantly on the production of renewable electricity, with solar and onshore wind being the most widely used technologies (DECC, 2014a). The Literature indicates that the majority of CRE projects are multifaceted which means they are involved in different types of activities including raising energy awareness, and ensuring efficient RE generation (DECC, 2014a). According to the literature, the number of community energy projects which are exclusively involved in raising energy awareness or improving energy efficiency is higher in deprived areas. A study conducted by the DECC (2014a) indicated that the majority of community energy projects are located in rural areas of Scotland and South West England. The distribution of community energy projects in England particularly in London was disproportionate to other parts of the UK, with only around 4% residing in the capital (Seyfang et al., 2013).

However, since 2013 the activity of CRE projects in England has increased with the support of several policies have been introduced in recent years which explicitly aim to provide support for developing CRE projects across the UK. According to Community Energy England (2017), the CRE sector has raised £28 million of community investment in localised RE projects. On top of this, 155,000 voluntary hours have been designated purely to developing these projects, which is the equivalent of £5 million. £23 million pounds of the income from CRE projects has gone towards community benefit funds in order to combat fuel poverty (Community Energy England, 2017).

2.5.2 Government Support for the UK CRE Sector

Since 2000, community energy activity in the UK has been supported by the Government through various grant programmes (Walker et al., 2007). However, the literature argues that despite community energy activities being supported by the Government since 2000 there has been little progress in the UK's CRE sector comapred to other European countries (Walker et al., 2007; Allen et al., 2012; Nolden, 2013a). This can be because the majority of these early government-funded schemes were 'start-stop' by nature with different programmes ending and changing over the years (Martiskainen, 2014).

2.5.2.1 Key Support Schemes for Community Energy Development in the UK from 2010 onwards

From 2010, the UK Government has adopted several policies which explicitly aim to support CRE development in different regions of the country, including the Ynni'r Fro programme in Wales (Welsh Government, 2014), the Community and Renewable Energy Scheme in (Scotland) (The Scottish Government, 2011), the Community Energy Strategy in 2014 (UK),

Table 2.1 A Summary of CRE Funding Schemes in the UK after 2010 (Walker et al., 2007; Gubbins, 2010; Cherrington et al., 2013; Nolden, 2013; BRE, 2014; Energy Saving Trusts, 2015; DECC, 2014b; DECC, 2014a)

Name of Scheme/Incentive	Period	Aim	Policy Target	Total Funding (£)
The Urban Communities Energy Fund	2014 to July 2016	Support RE generation in urban areas from the point of feasibility study to planning application	RE sources in urban communities across England	£10 million
The Rural Community Energy Fund	2013 – ongoing	Support RE generation in rural areas from the point of feasibility study to planning application	RE sources in rural communities across England	£15 million
Tax Relief schemes: Enterprise Investment Scheme (EIS) and Seed Enterprise Investment Scheme (SEIS)	2012 to November 2015	To encourage investment in RE projects by providing Tax Reliefs to early-stage companies	The EIS covers hydro and anaerobic digestion (AD), or projects which are run by community interest companies, co-operative societies, or community benefits societies.	EIS investment up to £1,000,000 in any tax year and receive 30% Tax Relief SEIS 50% on investment up to £100,000 and capital Gains Tax
Renewable Heat Incentive (RHI)	2011--ongoing (2014 for domestic sector)	Supporting communities and organisations to install heat technologies	RE heat for communities and organisations covers, Solar Thermal, Bio Energy, AD, air source heat pumps, ground source heat pumps, biomass boilers and biomass stoves with integrated boilers and solar thermal panels	p/kWh renewable heat generation
Local Energy Assessment Fund (LEAF)	2011 to 2012	Encourage communities to improve energy efficiency and renewable energy	RE Communities in England and Wales	£10 million
Feed-in-Tariff (FIT)	2010-ongoing (65% reduction in 2016)	Supporting small-scale RE (up to 5MW)	All RE sources for communities, individuals and, businesses across the UK	p/kWh RE generation
Ynni'r Fro programme	2010 to March 2015	Support RE generation in early stage of development	CRE projects across Wales	Pre-installation grants: up to £30,000 Capital cost loan for installation: up to £250,000
Community and Renewable Energy Scheme (CARES)	2011-ongoing	Support RE generation in its early stages of development	CRE projects across Scotland	Feasibility grants: up to £20,000 Pre-planning loan: up to £150,000

and the Urban Communities Energy Fund (UCEF) in England (DECC, 2014b; Centre for Sustainable Energy, 2014), just to name a few (Table 2.1).

In addition, UK incentive scheme for promoting RE changed from being associated with capital funding to revenue payment in 2010, with this came the introduction of the FIT and RHI which both created a viable income for CRE project (Gubbins, 2010). The FIT was introduced in the UK on 1st April 2010, with the aim of supporting small-scale (<5MW) renewable electricity generation.

This policy was one of the most successful in boosting small-scale generation by domestic, commercial and community-based projects (Nolden, 2015). FIT emerged as a prominent international policy for the promotion of renewable energy and by 2011, it was being implemented in 80 countries around the world (Muhammad-Sukki et al., 2013). The primary aim of FIT was to reduce the cost of technologies, and to provide security for long-term investors (Cherrington et al., 2013). The scheme provided a guaranteed income to RE developers by making payments to small-scale generators, dependent on the amount of electricity generated (DECC, 2015f). The UK's FIT also had a significant influence on the solar photovoltaic (PV) industry, increasing the financial viability of community-based RE projects (Cherrington et al., 2013; Nolden, 2013b). FIT was the main source of income for CRE projects as it provided reliable long-term financial security, something which was not available before its introduction (DECC, 2015b). For many community-led RE groups, FIT was described as a liberator from grant dependency (Nolden, 2013a).

However, since FIT introduction in 2010, FIT payments have significantly decreased, first in 2012 for payments towards solar PV generation, and a second time in 2016 for all eligible technologies, making this support scheme somewhat cumbersome

(Martiskainen, 2014). For example, in 2012 the generation tariff for producing less than 4 kWh of solar PV energy on a retrofit house was cut by approximately 50%, and for stand-alone systems by around 71%, causing much frustration among those wishing to install solar panels (Muhammad-Sukki et al., 2013).

Although the FIT scheme was very successful in the carbon emission reductions and promoting renewable electricity technologies, it is argued by UK Government that it increased average domestic bills slightly more than the initial prediction (Nolden, 2015). Policies such as FIT that promote the diffusion of RE technologies which are immature through levies on energy bills usually increase average domestic electricity bills as they act as a form of regressive tax (Nolden, 2015). Consequently, in the second half of 2015, the Government announced another dramatic cut to FIT, which would come into effect in January 2016 with periodic degression (DECC, 2015a).

Table 2.2 Overview of FIT Reductions (Complied from Ofgem, 2016b)

Technology	Band (kWh)	Jan to April 2016 Rates (p/kWh)	Apr to Jun 2016 Rates (p/kWh)	% Reduction	Degression and Frequency
Hydro (Run of River)	0-15	15.45	7.68	50.29%	Annually 5%
	15-100	14.43	7.68	46.77%	Annually 5%
	100-500	11.40	6.14	46.14%	Annually 5%
	500-2000	8.91	6.14	31 %	Annually 5%
	2000-5000	2.43	4.43	-82.30%	Annually 5%
Solar PV	0-4	12.47	4.32	65.35%	Quarterly 3.5%
	4-10	11.30	4.32	61.76%	Quarterly 3.5%
	10-50	11.30	4.53	59.91%	Quarterly 3.5%
	50-150	9.63	2.38	75.28%	Quarterly 3.5%
	150-250	9.21	2.38	74.15%	Quarterly 3.5%
	250-1000	5.94	1.99	66.49%	Quarterly 3.5%
	1000-5000	5.94	0.74	87.54%	Quarterly 3.5%
	Stand Alone PV	4.28	0.74	82.71%	Quarterly 3.5%
Wind (On Shore)	0-50	13.73	8.46	38.38%	Annually 5%
	50-100	13.73	7.61	44.57%	Annually 5%
	100-1500	5.98	4.89	18.22%	Annually 5%
	1500-5000	2.49	0.85	65.86%	Annually 5%

The reduction of FIT rates in 2016 largely affected the solar industry, with the average quarterly deployment of solar energy dropping by 67% (from quarter 1 to quarter 3, 2016) within a year (Table 2.2).

The Renewable Heat Incentives (RHI) was introduced in 2011, in order to encourage the uptake of renewable heat technology amongst communities and organisations (DECC, 2014a).

The Department for Environment, Food & Rural Affairs (DEFRA) and the Department of Energy and Climate change (DECC) together launched the Rural Community Energy Fund (RCEF) in 2013. This fund provided £15 million towards the development of RE projects from feasibility study stage through to planning application (DECC, 2014b). Following the RCEF, the Urban Community Energy Fund (UCEF) was launched in November 2014, providing the same support to urban communities. UCEF provided £10 million to kick-start RE projects in urban communities across England, from the point of feasibility study to planning application (Centre for Sustainable Energy, 2014).

The scheme delivers roughly £150,000 of funding for feasibility and pre-planning study of CRE projects. It provides both grants and a loan, with maximum grant being £20,000 and the maximum loan being £130,000. These loans are ‘contingent,’ in that they do not need to be paid back if a project fails before it reaches construction phase (Centre for Sustainable Energy, 2014 and DECC, 2014a).

The Green Deal was a UK Government initiative which provided funding for homeowners to improve their energy saving and measure of renewable energy through a loan. It was introduced in October 2012 and phased out in July 2015 without any replacement. The Green Deal was unpopular with the public, largely due to its complexity and lack of marketing (RegenSW and Klimaatfonds, 2015).

In 2014 the UK Government allowed the Green Investment Bank to support small RE projects across the UK. Beginning in November, the Green Investment Bank allocated £200 million of support to the CRE sector in the UK. The principal aim of this scheme was to provide financial support for community wind energy projects which generated less than 18MW and hydroelectric projects generating less than 8MW (Green Investment Group Limited, 2014).

In addition to the different grant programmes and measures applied by the UK Government to support and promote its community energy groups, the CRE sector has also received support from non-governmental organisations, businesses and local authorities. This includes Scottish and Southern Energy (SSE's) utility community fund (SSE, 2017), the National Lottery's Big Lottery Fund (Big Lottery Fund, 2011) and the Co-operative group's community funds (Cooperative Energy, 2014), to name a few. Further to these, Community Benefits Funds have been implemented to share the benefits of developed CRE projects with communities living around renewable energy sites. The money is intended to fund community and environmental projects.

In an attempt to break down the predominantly financial barriers facing the development of the UK's CRE sector, the Government has introduced various Tax Relief schemes including the Enterprise Investment Scheme (EIS) and the Seed Enterprise Investment Scheme (SEIS). The EIS covered hydro electricity generation and Anaerobic Digestion (AD), and specifically projects which were run by community interest companies, co-operative societies or community benefits societies (HM Revenue and Customs, 2017). The SEIS was launched in April 2012 in order to encourage investment by providing Tax Relief to early-stage organisations (HM Revenue and Customs, 2017). However, community energy projects were excluded from the EIS on 30th November 2015 (HM Revenue and Customs, 2015).

2.5.3 Changes to the UK's CRE Funding Scheme

Recent community energy policies in the UK appear to be contradictory. On 27th January 2014, the Government published its first ever Community Energy Strategy (DECC, 2014b) and highlighted the effectiveness of community-led action in tackling the challenges facing the country's energy system. The Strategy explicitly stated that:

'*Community-led action can often tackle challenges more effectively than Government alone, developing solutions to meet local needs, and involving local people'* (DECC, 2014b pp.7*).*

Contrastingly, not very long after that statement was made, many key renewable support mechanisms were scheduled to close or end. This included the announcement of the closure of RO scheme for new onshore wind projects a year earlier than originally planned, in June 2015 (DECC, 2015a), the sell-off announcement of a significant majority of the Government stake in Green Investment Bank in June 2015 (Environmental Audit Committee, 2015), the closure of Green Deal communities in July 2015 (DECC, 2015d), the exclusion of community energy projects from the EIS on 30th November 2015 (HM Revenue and Customs, 2015), the exclusion of onshore wind from a second allocation of Contracts for Difference (DECC, 2015c), the announcement of the removal of pre-accreditation and pre-registration for FIT, and the major reduction in the FIT rates on 17th December 2015 (DECC, 2015f).

2.5.4 Barriers Facing the Growth of CRE Projects in the UK

The major hurdle encountered by any kind of grass-roots innovation is maintaining a viable, sustainable socio-technical space within a wider unsustainable regime (Seyfang and Haxeltine, 2010). This can be related to the challenges around secure funding, which can lead to possibilities for institutionalisation, managing structural change, making effective networking activity (Seyfang and Haxeltine, 2010).

These barriers can be categorised into four groups: economic and financial, institutional, technical and cultural.

As indicated in Figure 2.6, economic and institutional barriers are the main obstacles facing the development of the UK's CRE sector. Financial barriers, such as the difficulty of attracting new investment, particularly during the feasibility study and planning stages, are a key issue for CRE development. This is partially due to the structure of the UK's banking and energy systems, which limit the growth rate of CRE projects. Unlike bigger commercial organisations, community groups rarely have the assets to borrow against, or a portfolio of potential projects over which to spread the financial risk. As a result, developing projects poses a huge financial risk because they are not always guaranteed to go ahead. Depending on the scale of the project and the technology used, a project may require over £100,000 in the initial feasibility study and planning stages, an amount which the private sector is rarely interested in investing (DECC, 2014a). In addition, the financial cost is usually higher than it would be for a commercial developer. One of the problems for potential investors is that the rate of project failure is currently unclear, making it difficult to accurately calculate the financial risk. Given that the loans provided for community energy projects are relatively small, fixed expenses, such as due diligence can contribute to a significant percentage of the loan (DECC, 2014a).

In order to overcome the financial barriers preventing the development of RE projects, the UK Government introduced new energy policy measures such as the FIT and RHI. Emerging co-operative ownership schemes also proved to be successful.

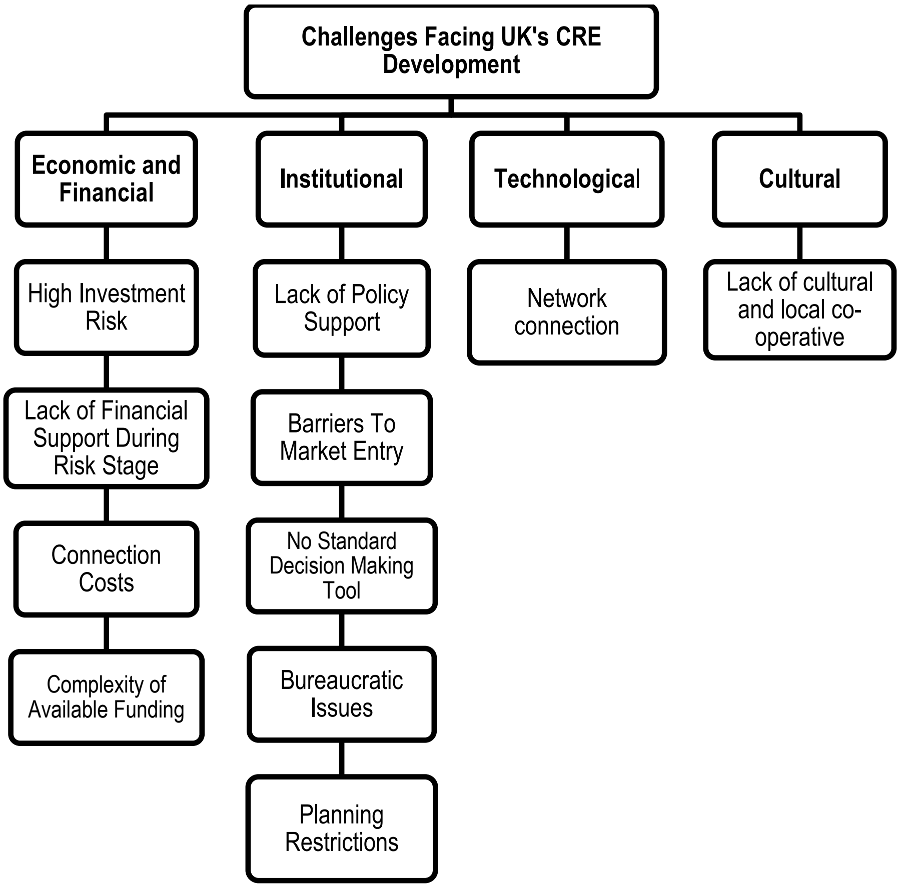

Figure 2.6 Key Challenges Facing the Development of the CRE Sector in the UK (prior to the reduction in FIT rates)

However, since the major reduction in FIT rates, the development of CRE projects once again faces huge financial challenges. According to the Community Energy Strategy, the FIT was previously the main source of income for the majority of CRE projects in the UK, as it offered a reliable long-term stream of income (DECC, 2014b). Most CRE project business models depend on Government grants to finance their projects, and public subsidies (FIT and RHI) for income and ensuring stability. Business models could be easily scalable and low-risk before the FIT rates were lowered. Since the reduction, these models are no longer economically viable for the future. As a consequence, it is extremely challenging for CRE organisations to develop further projects, and almost impossible for new groups to form and enter the sector. As this is a critical concern for the UK's CRE development, alternative approaches must be considered and taken to continue developing innovative projects.

2.6 Energy Transition in Denmark and Germany

The following section critically analyses the energy transitions that have taken place in both Denmark and Germany and evaluates the factors which have contributed to this change. Both countries are known to be international pioneers in the development of the CRE sector. While Denmark has a long history of citizen participation in energy transition, this is much more recent in Germany.

2.6.1 Danish Energy Transition

Denmark was the original pioneer in the development of wind energy, and also the front-runner in co-operative ownership. Denmark's energy policy has been extensively influenced by the oil crises of the 1970s, as its energy system was highly dependent on fossil fuel (Bohnerth, 2015). The Danish energy system transitioned from being 99% dependent on imported fossil fuels in 1970 to today being a net exporter of natural gas and electricity (Sovacool et al., 2008). This energy transition occurred as result of active involvement and investment of civil societies and citizens in the Danish energy system. In 2001, 23% of wind capacity in Denmark were owned by over than 100,000 local people (Bolinger, 2001). Similarly, 75% of district heating networks were owned by consumer co-operatives (Bolinger, 2001). Since the 1970s co-operatives have become a significant form of ownership for wind power projects (Mendonc et al., 2009). Approximately 20% of Denmark's total RE capacity is owned by local people (Mendonc et al. 2009). Additionally, in 2007 the Danish Government set a target that 100% of its energy supply would be generated from renewable technology by 2050 (Oteman et al., 2014).

Middelgrunden is one of the world's largest offshore wind farms that is co-operatively owned, and is Denmark's most established co-operative wind farm. The wind farm is 3.4 kilometres long and produces a capacity of 40MW, which is currently sufficient to provide electricity for over 40,000 homes in Copenhagen.

2.6.1.1 Contributing Factors to the Success Danish Energy Transition

Co-operative and collective organisation are rooted in Danish culture and have been utilised since the mid-19 century. The Danish energy transition was driven from the bottom up, with enthusiasts influencing the political process in such a way that the Government committed to providing conditions to boost the community energy sector. The energy transition was significantly influenced by two policies that encouraged collective ownership and investment in domestic wind energy (Haggett et al. 2014). These policies were the FIT and tax exemptions, as well as increasing investment subsidies by 30% for new wind energy projects. Furthermore, the Danish Government introduced a FIT in 1981, requiring utilities to buy electricity generated from local renewable energy projects at a higher rate than the wholesale market price of electricity in the area (Sovacool, 2013). Additionally, to promote community ownership and reduce cost for local projects, the Danish Energy Authority provided open and guaranteed access to the grids for community-based RE projects. Grid connection costs were usually shared between the owners of renewable projects and the electricity utility. The project owner was required to pay the costs of low-voltage transformers and connection to the nearest distribution grid. The utilities were responsible for covering costs for reinforcement of the distribution grid (Sovacool et al., 2008).

The success of the Danish co-operative sector is largely due to the accessibility of the grid and the legal obligation for electricity utilities to buy wind energy at guaranteed fair price (Sovacool et al., 2008).

2.6.1.2 Replicable Aspects of the Danish Energy Transition

According to Sovacool et al. (2008), a lot of the policies within Denmark are not easily replicable in other countries, as they have completely different economic structures. The Danish economy is extremely dependent on the service sector, with this contributing to over 76% of its income, and the country's industrial base is relatively small (Sovacool, 2013). Transport and buildings use the most energy in Denmark and therefore, other countries that rely on energy-intensive industries may not be able to replicate Danish energy policy and strategy (Sovacool, 2013).

Despite the particularities of the Danish energy system, at least some of its characteristics can be replicated. Firstly, the Danish financing model can also act as a useful tool for raising capital to invest in community-based RE projects around the world. Secondly, the Danish bottom-up approach to Research and Development (R&D) and energy process innovation can be replicable all around the world (Sovacool et al., 2008, pp. 35). In summary Denmark's overall approach towards its energy system provides lessons for other countries in how they can incorporate renewable energy socially as well as technically (Mendonc, et al., 2009).

2.6.1.3 The Impact of Changes to the Renewable Energy Support Scheme in Denmark

Within a year, the renewable energy support scheme in Denmark changed dramatically. In the early 2000s, the Danish energy market became liberalised and the FIT was replaced by market-oriented policies such as the RE portfolio standard and the emissions trading scheme, which was brought into practice in order to control the costs of renewable energy support schemes (Oteman et al., 2014). Changes to the FIT caused a decrease in the development of community-owned wind projects and an emergence of larger developments being run by corporations. The changes to FIT drove some co-operatives to sell their wind turbines to large, commercial investors (Haggett et al., 2014). However, in 2007 the Government began to place more pressure on the country's RE target, causing the support scheme to be changed back and FIT reintroduced in 2009 with a different payment rate for each renewable energy source (Oteman et al., 2014).

2.6.2 German Energy Transition

In Germany, there is a similar amount of support for RE projects, although the energy transition named 'energiewende' has only occurred in recent years. It was officially introduced in 2010 and became prominent after the nuclear disaster occurred in Fukushima in 2011, but its origins go back to the 1980s (Simcock et al., 2016). There is also strong institutional and public support for the community ownership of RE generation, with 46% of the total installed RE capacity in Germany being owned by the citizens, 41.5% is owned by institutions and energy suppliers only contribute to 12.5% of the total RE capacity (Haggett et al. 2014). The Renewable Energy Act in Germany was the main driver of energy transition (Roberts et al., 2014,Hall et al. 2015).

There is a wide range of RE resources available, but, solar co-operative projects account for the largest percent (57%) (Herbes et al., 2017). The number of community-owned solar projects increased dramatically in 2007 and reached over 431 by 2014 (Herbes et al., 2017). In 2010, it was estimated that over half of Germany's installed onshore wind capacity was owned by local investors (Oteman et al., 2014).

2.6.2.1 Contributing Factors to the Large Amount of Citizen Participation in RE investment in Germany

According to Haggett et al. (2014), the large involvement of citizens as investors in renewable energy can be explained by the financial characteristics and institutional framework of the country. According to Hall et al. (2015) and Haggett et al. (2014), local subsidiary, public benefits values and promotional lending fostered localised RE generation in Germany, while all of these factors are lacking in the UK. Additionally, municipalities are required to become carbon neutral, energy self-sufficient and to participate in the supply, generation and distribution of energy through municipal utilities (Simcock et al., 2016; Roberts et al., 2014). Local Government is often supportive of CRE development and encourages the national Government to help finance those projects (Simcock et al., 2016).

To summarise, the German Government highly prioritised the process of energy transition, which in turn encouraged and increased public acceptance of renewable energy, playing a significant role in the success of localised energy projects (Simcock et al., 2016).

2.6.2.2 Impact of Changes in Germany RE Policy

RE co-operatives in Germany have been affected by the recent RE policy changes, including the reform of the Renewable Energy Association (REA). This reform involved a significant reduction in FIT rates which made solar co-operative projects less profitable. Approximately, 80% of co-operative RE projects relied on the income from of FIT scheme. Consequently, the number of new RE co-operatives entering the market in Germany decreased between 2014 and 2015, with only 40 new organisations being established in 2015, compared to 167 in 2011 (Herbes et al., 2017). Currently, German co-operatives are in a similar position to many of the UK's CRE projects and face new challenges as they attempt to create innovative business models.

2.7 Current Discussion on the Development of the UK's CRE Sector

In the UK although, there are enough RE sources which would be suitable for community-owned projects, CRE projects have only grown from less 0.01% in 2005 to just under 0.4% of the UK's total RE sector (Harnmeijer, 2016). It is widely argued that despite the policy mechanisms put in place between 2010 and 2016, and community energy activities being supported by the Government since 2000, there has been little progress in the UK's CRE sector (Walker et al., 2007; Allen et al., 2012; Nolden, 2013a). A wide range of quantitative and qualitative studies have been conducted, particularly between 2005 and 2013, to investigate why the development of CRE projects in the UK has been so slow in comparison to other countries within the EU, such as Germany and Denmark where local people own 46% and 20% of the installed renewable energy capacity respectively (Seyfang et al. , 2013; DECC, 2014a; Haggett et al., 2014; Harnmeijer, 2016a).

Bolinger (2001) and Walker (2008) have suggested that the UK's lack of history in using local co-operative organisations to generate energy has contributed to the slow progress experienced by localised RE projects today. The UK has little history of stakeholder involvement in energy projects, with most of its projects being planned centrally or by the private sector. Infrastructure and technology projects tend to be driven by economic aspects rather than by a broader environmental or social cause (Walker et al., 2007).

According to Walker (2008), most RE policies were not conducive to support CRE development in the UK. Nolden (2013a) highlights that most policies and strategies in the UK are more committed to helping develop and support centralised large-scale renewable energy supply through utilities, rather than encouraging diversity in terms of scale and ownership models. Furthermore, the deployment and development of a renewable energy system can be a complicated process due to existing financial and bureaucratic barriers (Walker, 2008). Johnson et al., (2014) argue that, due to the UK's banking structure and centralised energy system, CRE projects face huge financial challenges which ultimately limit their growth. Martiskainen (2014,pp.91) states that '*Early government-funded schemes for community energy were start-stop in nature with different programmes ending and changing over the years'* which appears to still be the case (See section 2.5.3).

According to Hall and Roelich (2015a) and Haggett et al., (2014), local subsidiarity, public benefit values and promotional lending have fostered localised RE generation in Germany while all of these factors are lacking in the UK. Likewise in Denmark, RE organisations have the right to access the national grid and electricity utilities are obligated to buy wind electricity at a guaranteed fair price, policies which do not exist in the UK.

Among the existing body of knowledge, a number of researchers have focused on the different factors that impact CRE development in the UK; for example, Walker (2008) focuses on policy aspects, including institutional barriers and incentives. Walker & Devine-Wright (2008) focus on CRE projects and providing a definition of community ownership models. Social factors such as impact, acceptance and social embeddedness have been explored by Allen et al., (2012), Rogers et al, (2012) and Schoor and Scholtens (2015). Other researchers have focused on the conditions created by institutional frameworks in various countries (Simpson, 2013; Li et al., 2013; Nolden 2013). Further dimensions which have been covered include multi-stakeholder engagement and the role of stakeholders in decision-making (Allen et al. 2012; Walker, 2008), community energy SNM and grass-roots innovation (Seyfang et al. 2013; Martiskainen 2014), the scale and structure of community wind energy (Bolinger 2001; Hargreaves et al., 2013), the FIT (Nolden, 2013), and community investment in commercial RE projects (Haggett et al., 2014).

Despite a wide range of studies and surveys being carried out, there is very limited data available on the current scale of activity and the barriers that face existing CRE projects in the UK, those which are operating following major changes in Government policy, which had a direct economic impact on community-led innovation. The CRE sector is a new and evolving sector, and therefore, there is a strong need to continue conducting research over time and keep track of the sector's development (DECC, 2014a).

2.8 Evaluation of the Business Model

The concept of the business model has commonly been used as a tool to analyse and classify companies and their activities (Herbes et al., 2013). Similarly, the business model Canvas presented by Osterwalder (2004) has been used by several researchers to examine renewable energy enterprises. For example, Aslani and Mohaghar (2013), and Richter (2011), classify renewable energy business models on the basis of the key resources that they use (types of renewable energy technology) and the key activities that they involve, such as generation, transmission and distribution. However, it has been argued that applying the concept of the business model to non-profit organisations is 'unorthodox,' as the concept was traditionally designed to analyse firms that make a profit. Nevertheless, the fundamental definition of the business model, which focuses on the way a firm operates and creates value for its stakeholders, can also be applied to co-operatives and other social enterprises (Baden-Fuller and Morgan, 2010; Herbes et al., 2017).

2.8.1 Overview of Existing of UK's CRE Business and Ownership Structure

Asmus (2008) defined community renewable business models as 'the collective participation of local people who do not have access to RE resources, fiscal capacity or ownership rights in RE activities, purchasing shares in the total output from energy generation of renewable technologies, or supplying electricity to community buildings (community centres, schools) without any need to pay an upfront cost or tackle installation challenges.' This type of business model can lead to cost efficiency and therefore, more efficient energy projects (Huijben & Verbong, 2013). Moreover, involvement by local people in renewable energy investment has many benefits for communities, such as strengthening local support for new energy infrastructure and RE investment, engaging people with the concept of RE and decreasing 'Not In My Back Yard' (NIMBY) opposition to wind development (DECC, 2014). Having ownership and responsibility for RE projects can increase a community's trust in local energy projects and reduce opposition. Generally, business models are largely focused on revenue, cost, margins, and sales, although some versions also enclose social aspects such as leadership and governance, while business models for community energy organisations place value on revenue generated from their activities and their success in achieving their social aims (RegenSW and Klimaatfonds, 2015). CRE projects can be developed in different ways, through grass-roots action, a partnership between communities and other organisations, or they can be initiated by entrepreneurs and utilities. These different opportunities already indicate diverse innovative organisational and financial frameworks, legal conditions, business models, and ownership arrangements (Hielscher, 2011).

Due to the variety of stakeholders and services provided, a business model for a community energy project will be slightly different to those which are suitable for large-scale centralised projects. CRE organisations can adopt different legal structures, depending on the law and regulatory procedures within a country and the proposed financial activities.

Table 2.3 outlines the most common stakeholder options for development of CRE projects for investment in the CRE sector. Due to the variety of stakeholders and services provided, a business model for a community energy project will be slightly different to those which are suitable for large-scale centralised projects. CRE organisations can adopt different legal structures, depending on the law and regulatory procedures within a country and the proposed financial activities.

Table 2.3 The UK's CRE Stakeholder Options Based on Literature Review
source: (Bridge and Fenna, 2015; DECC, 2014a; Seyfang *et al.*, 2013)

Financer	Members of community/ Co-operatives	Commercial Developer/ Bank	Local Authorities/ Government	Development Finance Institutions/NGO
Owner	Members of Community/ Co-operatives	Commercial Developer	Non Beneficial Owner / Local Authorities	NGO
Operator	Members of community/ Co-operatives	Local Distributer Network	Energy Company	
Maintenance	Private Company	Utility	Local Technician	
Customer	End users or Residents	Members of Community/ Co-operatives	National Grid	

The different types of legal and ownership models which have been adopted across the UK include co-operatives, community charities, development trusts and shared ownership models. According to an online survey that the DECC conducted in 2014, the dominant legal structure in England, Northern Ireland and Wales is that of community charities and Industrial Provident Societies (IPS), while in Scotland, community development trusts dominate (DECC, 2014a). Figure 2.7 provides a summary of the different ownership models and legal structures adopted by CRE organisations across the UK.

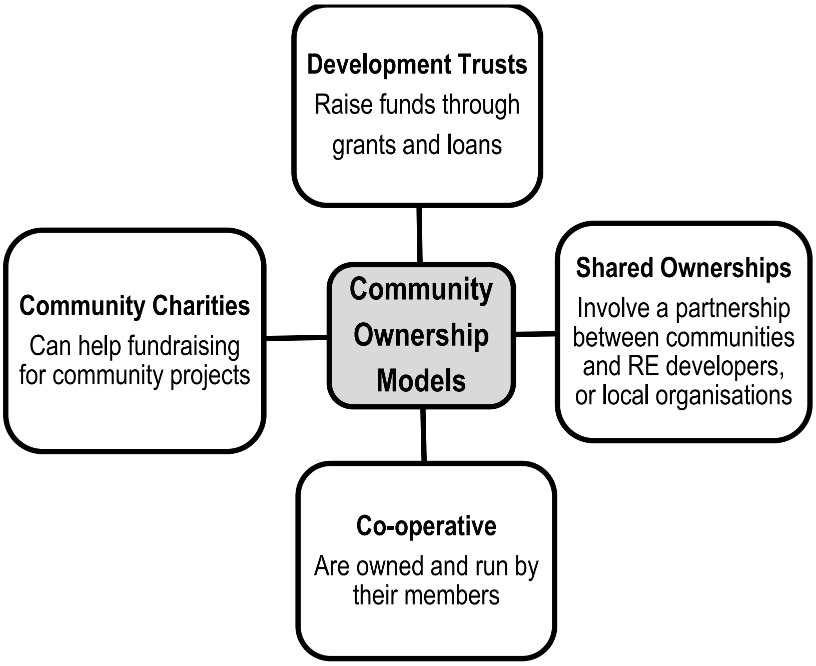

Figure 2.7 The Ownership Models Adopted by CRE Projects in the UK ,(Willis and Willis, 2012; Haggett et al., 2014; Haggett And Aitken, 2015)

Co-operatives are owned and run by their members, whose aims are to achieve common social, economic, and environmental requirements. In Europe, Denmark has the strongest co-operative energy sector, and it also has distinctive experience in using a variety of RE technologies. The members of co-operative CRE projects can wear multiple hats incorporating ownerships, investment and consumer, each role being related to decision-making. By buying shares and therefore becoming the owner and investors (depending on organisational framework), members can participate in the running the organisations and receive a return on their investment. In addition, by financially participating in the projects, they have the right to use its services. The first co-operatively owned wind farm in the UK was Baywind in Cumbria, which started operating in in 1997, using a model transferred from Sweden. However, in the UK there are also many co-operative societies CRE projects which are registered before

2014 and referred as Industrial Provident Societies (IPS) and if they are registered after 2014 they are referred to community benefit societies (Haggett et al., 2014).

In the literature, it has been argued that the co-operative structure can potentially weaken social cohesion, since the benefits are limited to individuals who are able to invest a substantial amount, and therefore some members of society cannot benefit from the projects (Haggett & Aitken, 2015). However, since 2014 the majority of UK's co-operative is structured as a community benefit society which serves the broader interests of the community in comparison with other forms of co-operative that serves the interest of members.

The Literature has also highlighted the different challenges facing CRE groups that have a co-operative structure. For example, sourcing investors for co-operative structures can be challenging as it is often the case that a charitable funder may not be interested in investing in a profit-making organisation. Conversely, big investors such as commercial banks predominantly focus on commercial return and do not always place value on community profits. Some scholars also argue that the co-operative status becomes ambiguous when dealing with government organisations such as local authorities because governmental organisations cannot determine the difference between multinational, large-scale projects and community projects (Willis and Willis, 2012).

However, in the recent years the majority of UK's co-operative and community benefits societies raise fund through community share or crowd sourced debentures. Community share operates by selling a share to the member of a community in return shareholders receive a certain percentage of profits from the project. In this arrangement, shareholders have a role as a co-operative member, and they are responsible for making decisions regarding project income. Profits from the project can be shared among shareholders or used for community benefit (Haggett et al., 2014). Crowd sourced debenture approach, allows individual energy projects to raise funds directly from member of the community by selling debenture to members which effectively work as loans (DECC, 2015e).

The majority of co-operatives are heavily dependent on volunteers and their expertise, and some groups even believe that by paying employees, the projects could lose their 'community feeling' (Willis and Willis, 2012). However, if an organisation is dependent on volunteers, it must maintain their motivation and commitment throughout the length and unstable planning stage of development (Haggett & Aitken, 2015).

According to the online survey conducted by the DECC in 2014, around 14% of CRE groups in the UK have adopted a charity structure (DECC, 2014a). The structure of community charities restricts the work that can be carried out by the organisation, the board of trustees must not be paid, and the charity cannot raise equity investment.

Development Trusts are largely used in Scotland, with the majority being registered as companies limited by guarantee (Cooperatives UK Legal Team, 2009). Under this model, communities raise funds through grants and loans and distribute income to community projects (Haggett and Aitken, 2015), delivering various advantages to communities such as providing long-term commitment from an investor and creating jobs for community members.

A shared ownership (partnership) model was proposed by the UK Government in 2014 in its Community Energy Strategy to boost CRE project development in the UK (DECC, 2014b). This model can be sub-categorised into three types: joint venture (JV); split ownership; and shared revenue arrangements (DECC, 2014b; Haggett et al., 2014) . JV projects involve a partnership between communities and RE developers, or local organisations which are able to cooperate. In this ownership model, the developer benefits from building a valuable relationship with the local community, whilst simultaneously the community benefits from the partnership, as the developer provides the experience and expertise required to deliver large-scale energy projects (DECC, 2015e). The JV model can be split into two forms: the equity partner model, and the community shared model. Community shared models work when community-owned organisations buy stocks in a particular project, and receives surplus from the electricity trading. For example, community benefit organisations which buy stocks in commercial projects are using a community shared model (Harnmeijer et al., 2013).

Under the split ownership model, a project is split over two or more separate generation plants, one of which is owned and run by communities. The other owner, or owners, can be commercial developers or utilities. This model was implemented on a wider scale before the reduction of the FIT generation rate. However, the literature argues that the model poses several issues, one of them being that spilt ownership creates an element of risk for both parties, as both potential owners are to some extent dependent on the other for completion of the projects. Furthermore, both partners can face challenges such as difficulty in to accessing funding (Wolfe, 2014).

Under shared revenue arrangement models, the community buys a share in a commercial project and receives a percentage of the revenue. However, the CRE group only owns the income stream and does not own any physical assets. This approach means that commercial partners are owners and are therefore responsible for the operation, maintenance, and installation of the renewable energy technology (DECC, 2015e).The benefits of this model include community investors being protected from any development and construction risks, commercial developers receiving community support, and further funds, such as Tax Relief, being available to CRE groups (DECC, 2015e).

Existing literature highlights a number of hurdles that shared ownership models in the UK face, such as financing, which has been cited as the main challenge for different types of CRE ownership models despite the available funding and support, the lack of knowledge and skills from both partners, and the lack of trust between the community and the commercial developer (Harnmeijer, 2016a, Haggett et al., 2014).The requirement for community groups to invest money in projects without having received immediate interest can often create distrust between local people and developers. This issue can be taken further, due to misunderstandings and a lack of clear communication between the partners (Haggett et al., 2014).

2.8.2 An Evaluation of the Current CRE Business Structure in the UK

Many researchers have focused on the different elements that make up the business structure of CRE organisations. Seyfang et al. (2013) and Walker et al. (2007) conducted a broad survey of the entire community energy sector, offering insight into the key activities and geographical locations of its projects. The diversity of the organisational structure and ownership models used by CRE projects in the UK has frequently been evaluated in academic research, (Hielscher, 2011, Willis and Willis, 2012; Haggett and Aitken, 2015). However few have used the business model Canvas as an analytical tool to classify CRE projects. This thesis used the revised Osterwalder business Canvas to critically explores four fundamental areas of the UK's CRE business model structure: the value proposition; the customer interface; the infrastructure; and the revenue model (Osterwalder, 2004; Osterwalder et al., 2005). This way of mapping the different elements of the business model offers an in-depth understanding of the character of the UK's CRE sector, allowing for the assessment of alternative business models in post-subsidy conditions (Herbes et al., 2017). Huijben & Verbong (2013) have also emphasised that the analysis gained from the business model mapping method enables the design of innovative and experimental business models in the future.

2.8.3 The Importance of Business Model Innovation in Energy Transition and the Development of the CRE Sector

According to Schneider and Spieth (2013), business model innovation can be defined as a fundamental modification to the way that firms create and capture value, and exceeds incremental adjustment to an existing business model. Business model innovation can play a crucial role in ensuring the social and environmental sustainability of an industrial system (Bocken et al., 2014). Innovative technologies can act as a driver for business model innovation, but some new business models, such as car-sharing do not necessarily require technological advancement (Bidmon and Knab, 2014). According to Bolton & Hannon (2016), business model innovation can involve the addition of new business activities, connecting activities in novel ways, or changing the way that an activity is carried out. As argued by Johnson & Suskewicz (2009), new technological paradigms require specific business models which are tailored to them. However, finding and deploying such an innovative business model is very challenging due to the following factors:

I. Profit margins for modern technologies are very low and most resources are assigned to the more profitable and established business activities.
II. Business models are embedded in an unstable and complex environment, in which relevant information can be difficult to identify.

Despite the importance and the role of the business model and business model innovation in a diffusion of sustainable developments, it is not yet fully understood by policy-makers and scholars. As the UK's CRE sector has made limited progress over recent years, there is little research on the role of the innovative business model. In September 2015, Ofgem published a discussion paper on 'Non-Traditional Business Models: Supporting Transformative Changes in the Energy Market' which highlighted the importance of business model innovation in the supplier market, as well as in the transition towards a low-carbon energy system (Ofgem, 2015b). The Government set up a Local Working Group to investigate and evaluate regulatory barriers facing community groups entering the local supply market (DECC, 2014b).

However, as the UK's CRE sector faces new challenges and must now consider alternative business models to ensure the economic viability of its projects, research into business model innovation becomes very important. In 2016, 10:10 Climate Action conducted a qualitative survey amongst the CRE sector and intermediary organisations in order to evaluate alternative approaches that CRE projects can take under the new renewable policy conditions (10:10 Climate Action, 2016). RegenSW and Scown, (2016) published a report on different local supply models available around the UK in 2016. Hall & Roelich (2016) examined current business model archetypes of current local suppliers, based on the value proposition and value capture. The following section provides an overview of the business model innovation that is taking place, and the pilot projects which are being launched in the UK.

2.9 Overview of Potential and Existing Innovative Business Models CRE Projects

Local energy supply is being encouraged as a way to increase the participation of the community in the energy system (Hall and Roelich, 2015). Business models for local supply projects have gained increasing attention as they adhere to the needs of small generators and communities that are finding it challenging to develop further CRE and RE projects following the reduction in FIT (Hall and Roelich, 2015).

Currently, there are a number of different options available for those wishing to develop local supply projects in the UK, under the existing regulation and commercial framework. These can be split into two categories: projects that involve a partnership between the generator and a supplier, and projects that rely purely on self-supply (RegenSW and Scown, 2016).

2.9.1 An Overview of Local Supply Models Available through Partnership with an Energy Supplier

Figure 2.8 illustrates the current types of local supply models which can be developed in partnership with a supplier.

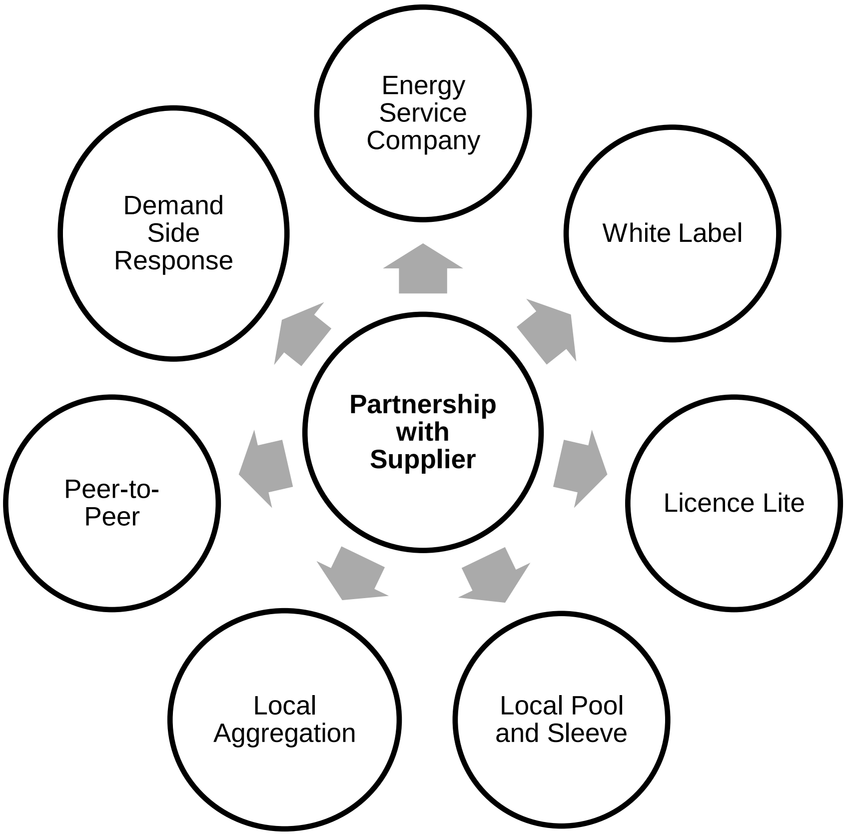

Figure 2.8 The Range of Local Supply Models that are Partnered with Suppliers (Complied by Author)

2.9.1.1 Energy Service Companies (ESCo)

An Energy Service Company (ESCo) delivers services such as hot water, and energy efficiency. An ESCo does not require a licence to provide unregulated services such as heat generation, but for electricity supply, partnership with a licenced supplier is required (RegenSW and Scown, 2016). Community ESCos can act as a potential investment model for energy efficiency in the near future. In the CRE sector BHESCo - Brighton & Hove Energy Services Co-operative is an example of established community-based ESCo which provides energy efficiency services to local people. However, currently there are no established ESCos for supplying electricity (Brighton & Hove Energy Services Cooperative, 2018).

2.9.1.2 Licence Lite

In 2009 the UK Government introduced 'Licence Lite,' which provides the opportunity for generators to become licenced suppliers without directly complying with industry codes. The main reason for introducing this option was the high cost of code compliance, as small generators were often unable to afford this. Licence Lite suppliers provide a direct supply of electricity to local customers, without having to involve a third party, hopefully encouraging more participation and involvement in community-based projects. However, this approach is yet to be properly put into practice (Scown and Regen Sw, 2016). The Greater London Authority (GLA) is one the example of the Licence Lite model and due to complex conditions, this is still under development.

2.9.1.3 The Local Pool and Sleeve Model

This model provides a form of direct supply and aims to aggregate renewable generation from a local area (pooling) and supply it to a specific end user without involving wholesale market intermediaries (Sleeving). Similarly to the introduction of Licence Lite, this form of direct supply involves complex regulations and cost conditions , as a result is not yet practiced in the UK (Hall and Roelich, 2015).

2.9.1.4 White Label Suppliers

A 'White Label' supplier operates in partnership with a licenced supplier, offers a different tariff under a separate brand. The licenced supplier must comply with industry codes, meeting various requirements such as metering and balancing. The disadvantages of this approach are that the White Label supplier cannot set a price for the energy it generates, and it is only applicable to large community groups (Hall and Roelich, 2015; RegenSW and Scown, 2016). Ovo Communities, which was set up by Ovo Energy, applies the White Label model, as it enables the purchase of electricity from local energy generators such as those set up by CRE groups, local authorities and housing associations (Ovoenergy, 2018).

2.9.1.5 Peer-to-Peer Supply Models

Peer-to-Peer supply models enable consumers to buy electricity directly from generators through virtual trading platforms, offering an alternative route to market for generators. This model has the potential to increase the appeal of CRE projects, therefore enabling them to sell electricity at a higher price. Like many other local supply models, the peer-to-peer model is still in its first stages of experimentation, and its technical structure is relatively new (Hall and Roelich, 2015). Although there are clear benefits of using this approach, there uncertainty surrounding the need to use the public network by end-user (consumer) (Hall and Roelich, 2015). Piclo, which was developed by Open Utility, together with Good Energy, is an existing example of the peer-to-peer local supply model being put into practice (Goodenergy, 2016).

2.9.1.6 Local Aggregation

An Aggregator model enables the interconnection between local consumption and local generation by employing virtual microgrids which use smart meters and the public network. This model operates with the introduction of half hourly metering for domestic consumers. This optimises and matches local domestic demand and generation through the concept of the Time of Use Tariff (TOUT), an automated process which shifts demand to a cheaper time of day (Hall and Roelich, 2015).The local Aggregation model has been deployed by Energy Local organisation which is based in Wales the following section provide an insight on how the Energy Local works.

Energy Local Case Study

Energy Local run the pilot project which utilises a local Aggregator model and is funded by Innovate UK. Putting the local Aggregator model into practice, Energy Local aims to inform market modelling with empirical data.

Energy Local enables a community to establish a co-operative organisation and negotiate with an energy supplier. Smart meters are installed for those within the community by the supplier. These meters monitor the amount of power consumed by households, and record the periods of high frequency. By using this model, the supplier can identify which households within a community are using surplus electricity from a local hydro project, when it could instead be sold back to the national grid. Households under this model pay £0.07 per kWh to local renewable generators, and electricity is supplied using a TOUT, with 4 set tariffs available when local generators are not in operation (Energylocal, 2018).

However, there are still questions about the approaches taken to determine local data from the supplier and Elexon (Hall and Roelich, 2015), as well as difficulties surrounding the switch from one supplier to another. This model requires more flexibility from customers, which could be enabled through the use of energy storage. This has previously been overlooked in literature, and further research into incorporating energy storage with local aggregation models is needed.

Figure 2.9 presents the framework of a local Aggregator model, with Distribution Network Operators (DNO) and Transmission System Operators (TNO) representing Aggregators that have the potential to contract demand side response services (Hall and Roelich, 2015). However, there has been little research into this type of model being used with DNOs or TNOs and so further investigation into its feasibility is required.

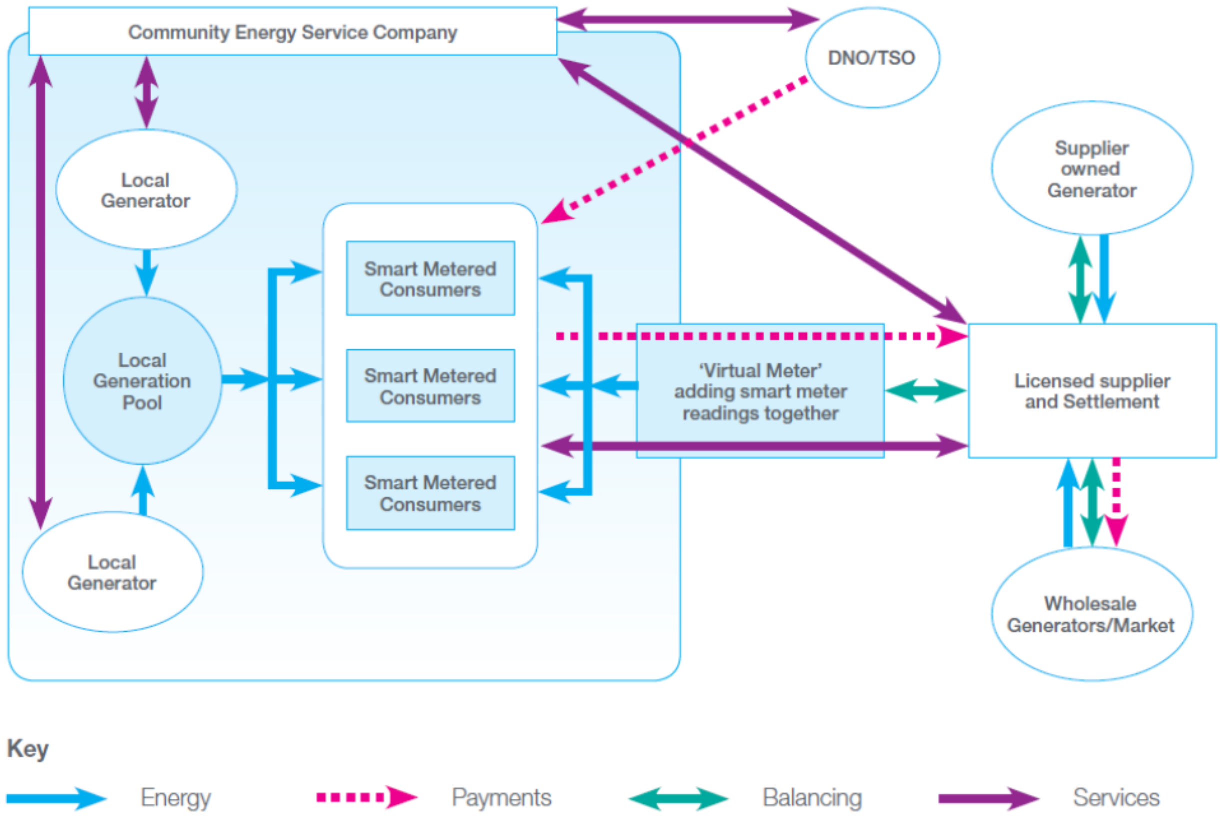

Figure 2.9 The Local Aggregator Archetype (Hall and Roelich, 2015)

2.9.1.7 Demand Side Response (DSR)

Literature classifies Demand Side Management into two different areas: i) Energy Efficiency (EE) which involves reducing the demand for the provision of a service or product (Please note the EE business model is out of the scope of this PhD). ii) Demand Side Response (DSR) which involves fluctuations in electricity demand as a response to changing electricity prices or incentives (Behrangrad, 2015). DSR enables end users to alter their demand of electricity from the grid (or other output), as a result of signals from the current supplier, infrastructure or system operator (Gillich et al., 2017). The main aim of DSR is to reduce energy consumption during various periods throughout the day, particularly those periods which are during peak time at power stations (Rodríguez-Molina et al., 2014). DSR can also be implemented in the electricity market by stakeholders as outlined in Figure 2.10. According to Behrangrad (2015), the DSR business model can be affected by various factors such as the market structure, the role of stakeholders within the electricity market, the capacity of the generation and transmission network, and the electricity tariff structure.

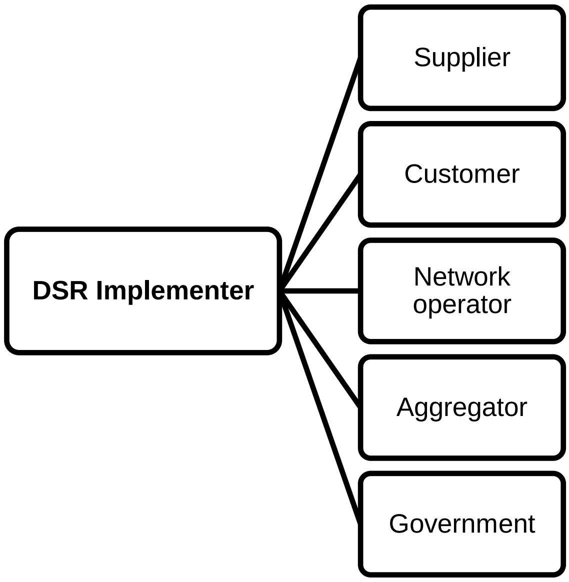

Figure 2.10 Demand Side Response Implementer (Complied by Author)

Sunshine Tariff Case Study

The Sunshine Tariff was introduced as a pilot project by Wadebridge Renewable Energy Network (WREN), in partnership with a licenced supplier. The project was run between May and September of 2016 in Wadebridge (North Cornwall), in order to test the concept of linking DSR to local solar generation and providing grid constraint management. Its primary aim was to connect solar farms in the area without creating any net effect results issues at higher voltage levels, enabling the connection of distributed generators in a constrained area (Western Power Distribution, 2015). This project represents an example of innovative demand side flexibility, in the way that it experimented with the TOUT (RegenSW and Scown, 2016). The Sunshine Tariff was designed to shift domestic electricity demand to the peak generation periods of solar farms between 10:00 and 16:00, which is when the national grid is under the most pressure (Western Power Distribution, 2015). This supply model required a virtual platform network which was run by a third-party supplier, enabling both the generator and the end user to manage their demand in real-time, using DNOs, and cutting the amount of energy generated when supply is greater than demand.

The Sunshine Tariff case study indicates that DSR based on the TOUT on a domestic buildings in not yet scalable or practical due to the lack of half hourly measurement in many domestic buildings, and the challenges associated with switching supplier (Western Power Distribution and Regen SW, 2017).

The TOUT may provide opportunities for CRE projects in grid constrained areas to become connected to the grid, consequently reducing grid connection costs. However, the Sunshine Tariff Model had two weaknesses which deemed it unsuccessful. The model was only tested in domestic buildings, and in order for a tariff user to shift their electricity demand to the middle of the day, this required users to be at home during this period which was unrealistic. The tariff also overlooked the importance of electricity storage in this model. A DSR model alongside battery storage may provide greater flexibility for the growing demand of technologies such as solar PV.

2.9.2 An Overview of Local Self-supply Models

Local self-supply does not require the involvement of a third party. As Figure 2.11 illustrates various local self-supply models.

The licenced supplier option is unfortunately not a suitable model for CRE projects due to its high cost (over £1 million), and the risk it poses as it requires compliance with a different range of industry codes. However, there are two examples of supplier initiatives run by local authorities within the UK, including Bristol Energy which owned by Bristol City Council and Robin Hood Energy which owned by Nottingham City Council (Bristol Energy Cooperative, 2017; Robinhoodenergy, 2017).

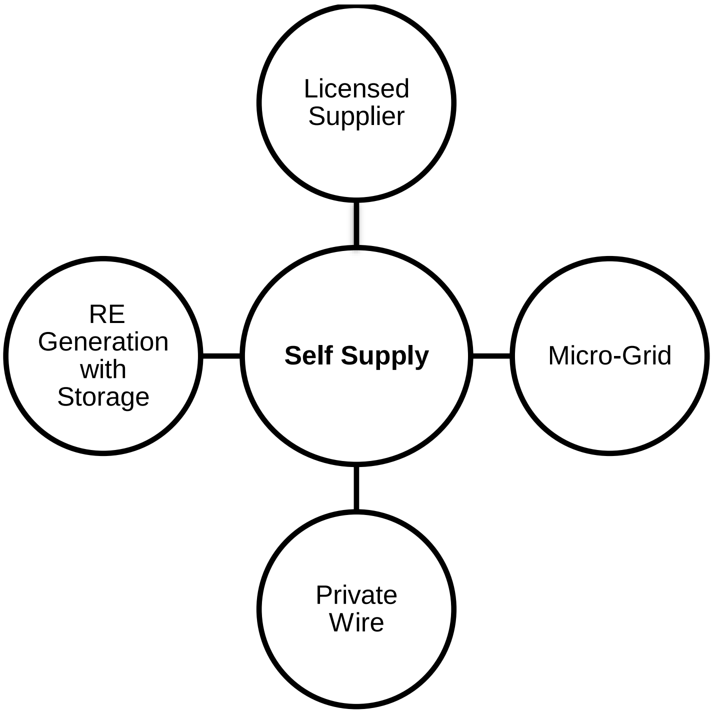

Figure 2.11 Local Self-Supply Models (Complied by Author)

A 'private wire' arrangement allows a renewable energy generator to directly sell power to neighbouring buildings without using the public network for electricity transmission.

A micro-grid is a small-scale independent power system which can operate independently from the main electrical grid. It provides a wide range of benefits for the energy system increasing the reliability of distributed generation, increasing the efficiency of electricity transmission and reducing the transmission distance. It allows generators to avoid the use of system charges and better price for the generator and end user. This option has many potentials for the distributed energy system in the near future, depending on the enhancement of technology. Nevertheless, this is a new concept that is still being developed, and would require significant capital investment due to its reliance on a private network and balancing technologies. It also raises the question of who should pay for the public network (Regen SW Conference, 2017).

2.9.3 Combining of Renewable Energy Generation with Electricity Storage

Among all local supply models that have been reviewed in the previous sections (2.9) the integration of RE with storage could have the potential to be an alternative model for CRE projects in post-subsidy conditions, because it enables RE generators to create revenue as well as providing flexibility and reliability within the entire energy system. Electricity storage technologies can be implemented in different stages of the energy system, including generation, transmission and distribution (He et al., 2011).

The literature has also highlighted the importance of electricity storage in post-subsidy conditions in the UK (Department of Business Energy and Industrial Strategy and Ofgem, 2017; Jones et al., 2017). With the reduction of the FIT rates, integration battery storage and renewable energy is an idea that has gained increasing attention and is now considered as a potential option for ensuring the sustainable generation of RE (Jones et al., 2017). However, currently it cannot be denied that the financial viability of this type of model is still in question, and further research is needed to assess its feasibility (Eunimia, 2016).

Various scholars have begun to explore the potential opportunities of integrating battery storage and RE, such as Jones et al (2017), who investigated the financial viability and Life Cycle Assessment (LCA) of solar PV systems, including battery storage within non-domestic buildings. The financial feasibility of integrating electricity storage and wind farms has also been evaluated by Dufo-López et al. (2009). Other scholars have focused on the use of electricity storage at distribution level, evaluating its role in reducing demand during the peak times of a distribution network (Walawalkar and Apt, 2008). The economic feasibility of using storage systems to implement peak shaving (reducing electricity demand during peak price period) has also been explored by Telaretti et al. (2016). The majority of these studies indicate the low profitability of investing in storage in today's market conditions. This could be due to the fact that all studies have only considered one application of electricity storage, whereas He et al. (2011) highlight the importance of combining different types of battery storage applications in order to increase financial viability. As discussed in the previous sections, (2.9.1.6 and 2.9.1.7), the importance of storage in providing efficient DSR services in the UK, has been overlooked by many pilot projects. Consequently, this study investigates and analyses whether the integration of solar photovoltaic (PV) and electricity storage can be structured to provide DSR services creating a viable model for a distributed energy system and community-based solar PV projects in post-subsidy conditions.

It is predicted that in the future the number of domestic and non-domestic buildings which implement combined solar PV and electricity storage will steadily increase due to a decrease in the cost of battery storage. Households can go off-grid most of the time via combined solar PV and electricity storage system. However, this may result in an ever-decreasing number of consumers paying for using the full electricity network system which would potentially cause severe social implications. In the literature this phenomenon is referred to as 'load defection' and is already disrupting America and Australia by destroying the profitability of traditional energy supply. However, deploying storage through the community-owned projects would potentially address the threat of penalising low income households who might be negatively affected by ‘load defection’ (10:10 Climate Action, 2016; Maloney, 2018). Consequently, this study will develop a viable business model for community-owned solar projects in the UK which would potentially assist in deploying storage through the community-owned projects.

2.9.4 Overview of Electricity Storage and Implications of Policies in Support of Energy Storage

On July 24th, 2017, the department for Business Energy and Industrial Strategy (BEIS) and Ofgem published an industrial strategy to upgrade the UK energy system and to give consumers more control of their energy use (Department of Business Energy and Industrial Strategy and Ofgem, 2017). This report highlights the significance of sources of flexibility such as energy storage in shifting towards a more decentralised and low carbon energy system. In the energy transition period energy storage is considered to be a key enabler although requiring large capital investment it can deliver a wide range flexibility and valuable services (Power responsive, 2016; Department of Business Energy and Industrial Strategy and Ofgem, 2017).

The recent reports published by Department of Business Energy and Industrial Strategy and Ofgem (2017) highlight the recent changes to policy and regulations to support energy storage technology in the UK electricity system; these changes include:

1. The proposal to amend the Electricity Act 1989, defining storage as a separate subset of generation. This change in the definition of storage will enable

developers to own and operate grid-connected batteries more simply.

2. Ofgem proposed changes to Network charges for energy storage technologies. The proposed plan would remove Transmission and Distribution of Residual Demand charges for energy storage which is co-located and standalone (RegenSW, 2018). However, demand residual charges will remain the same for behind meter storage system with onsite loads. The proposal was in response to storage stakeholders who argued that they should not be charged for electricity network twice, i.e. as demand customer and as a generator.
3. Consideration regarding how co-located storage with existing renewable sites may affect projects which are accredited for FIT and RO. Currently, the installation of battery storage might lead to deferral of subsidy payment.
4. Ofgem proposed DNOs should facilitate quicker and cheaper connections for energy storage.
5. BEIS announced the Faraday Challenge on 24th of July 2017, which provides £246 million of government funds to support battery storage and Electric Vehicle (EV) innovation. The funding streams are available in three forms namely research, innovation and scale up.

2.9.5 The Growth of the UK's Energy Storage Market

Energy storage is not a new concept, as pumped hydro, flywheels, and stored heat have been part of the UK energy systems for many years. The first pumped hydro project in the UK was deployed in 1963 and currently, these projects have the highest total capacity among all proven storage technologies as outlined in Table 2.4 (KPMG LLP, 2016).

Table 2.4 Pumped Storage Projects in the UK Source: (KPMG LLP, 2016)

Project Name	Year of Start	Capacity (MW)
Dinorwig	1984	1,728
Foyers	1975	305
Cruachan	1965	440
Ffestiniog	1963	360

Currently, the UK has 40 different types of storage project either in construction or operational phase (DOE Global Energy Storage Database, 2018). The UK's interest in new type battery storage has been increased with the development of RE penetration and the increasing demand for flexibility and grid balancing services.

Table 2.5 gives an overview of the main existing energy storage technologies. For the scope of this thesis, we only focus on Electro-chemical storage particularly Lithium-ion storage since it has a longer lifetime compared to other Electrochemical batteries such as lead-acid.

Table 2.5 Main Energy Storage Technologies Source (Regen SW, 2016)

Storage Class	Example Of Storage Type	Cycle Efficiency	Response Time
Chemical	Hydrogen, Synthetic natural gas	30-45%	10 minutes
Electrical	Super capacitor	90-94%	Milliseconds
Thermal	Packed bed heat storage, Chillers	30%	Seconds to minutes
Electro-chemical	Lead-acid, Lithium-ion, Sodium-ion, Nickel-cadmium	75-95%	Milliseconds
Electro-mechanical	Flywheels, Pumped Hydro, Compressed Air Energy Storage(CAES)	80-87%	Seconds to minutes

Currently, with total installed storage of 3.25GW the UK is lagging behind some countries in terms of installed capacity for example China (with 32GW), Japan (with

28.51GW) and Germany (with 7.57GW) (DOE Global Energy Storage Database, 2018).

2.9.5.1 Cost of Storage Technology

The reason for the current emphasis on energy storage is a combination of the maturity of storage technologies and a decrease in the cost of storage, digital monitoring and communication technologies, which now provide more innovative opportunities for smarter storage solutions and business models.

The cost of energy storage systems depends on a range of factors including power output, storage capacity and other performance drivers and a summary of all these factors can be seen in Table 2.6 (KPMG LLP, 2016; Regen SW, 2016).

Table 2.6 Energy Storage Cost Drivers Source, Complied From (KPMG LLP, 2016; Regen SW, 2016)

Class Cost Drivers	Cost Driver Elements	Cost Reduction Over Time
Power Output	- Power conversion - Grid connection - Plant infrastructure - Power control system	Medium/high
Storage Capacity	- Storage modules - Storage system controls - Storage infrastructure - Site and space requirement - Battery technology	Very High
Other Performance Drivers	- Charge/discharge rate - Cycle efficiency - Lifetime - Response Time	--------

The cost of power output elements is predicted to fall although the rate of this reduction is anticipated to be moderate as the power output elements such as information and communication technology (ICT) integration are well established. Small scale battery storage in the built environment is relatively new, consequently with the growth in the global market and manufacturing capacity, a rapid reduction in the unit cost of battery storage is predictable. In 2015 it was predicted that the unit cost of Lithium-ion batteries would decrease up to 60% by 2020, with a steady decline of approximately 12% per year (Figure 2.12). The cost of Lithium-ion batteries has fallen in recent years due to a growth of electric vehicles and subsequent scaling up manufacture capability around the world including Tesla's Giga-factory in Nevada in the USA and BYD and Boston Power in Asia, this is expected to continue.

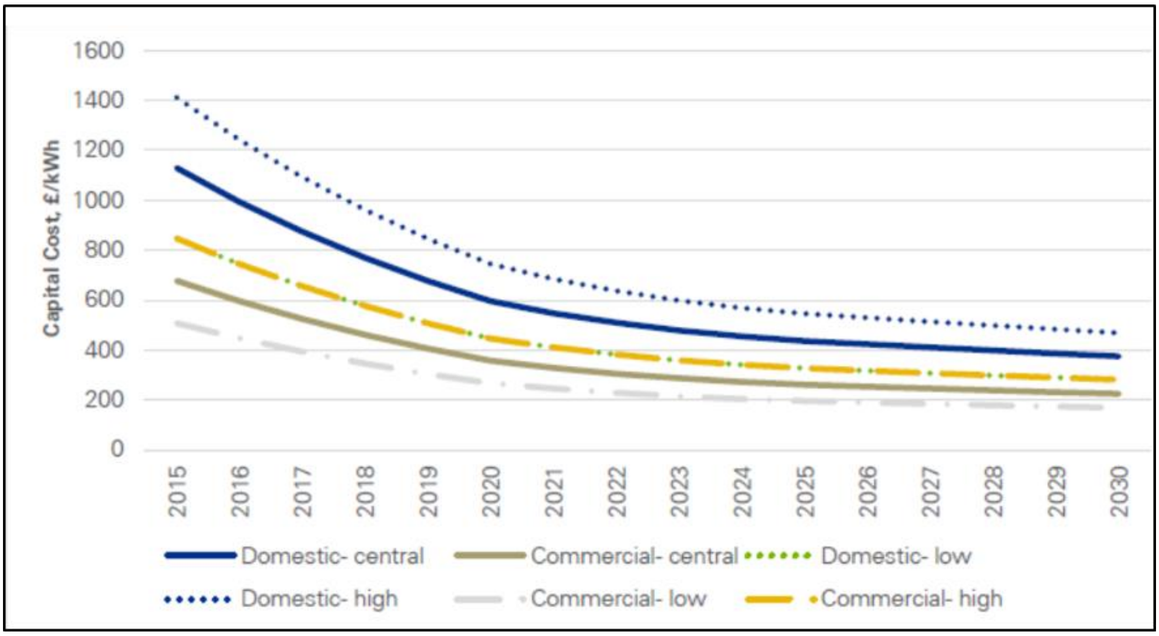

Figure 2.12 Lithium-Ion Battery Capex Reduction over Time (KPMG LLP, 2016)

Although a slower cost reduction rate is anticipated after 2020 (KPMG LLP, 2016; Regen SW, 2016). These cost predictions are generalised, and storage system costs will vary based on project specification including type of technology used and location of project site as well as, availability of grid connection (Regen SW, 2016).

2.10 Conclusion and Opportunity for Research

The literature review shows in order to transition toward low carbon energy system occur, a socio-technical change is required within the current energy system, involving adjustments to existing policy, infrastructure, culture and consumer practices. CRE projects have been proven to successfully bring about an energy transition is other European countries in particular Germany and Denmark. Since CRE groups can deliver sustainable development in a more meaningful way which is more directly related to people lives. The literature reveals therefore, that the UK's CRE projects have the potential to play a significant role in the UK’s energy transition.

This chapter has consisted of four parts. The first part provided a background to the UK energy system. The second part provided an overview of relevant theoretical frameworks, such as SNM and the concept of the business model; the third part investigated various factors that have contributed to the slow development of CRE projects in the UK. Findings show that the slow progress is not related to technological issues, but instead a wide range of economic, financial and institutional challenges. The literature has highlighted that although there is a significant amount of RE capacity in the UK which is suitable for community ownership, existing policies act as barriers to the development of the CRE sector, instead only supporting centralised and large-scale RE generation. Additionally, it has been argued that although the sector has been supported by the Government via different public subsidies and grants, this support was inconsistent.

Despite a wide range of studies being carried out before major changes to RE policy occurred, there is limited available research on the current scale of activity and the challenges facing CRE projects in the UK. Therefore, this study will present much-needed empirical data drawn from an independent survey and semi-structured interviews which explore the role of the business model in the recent development of UK CRE projects, and investigate the impact of the curtailment of renewable support mechanisms.

Existing literature shows that the most critical concern for today's CRE sector is the lack of consistent and reliable income available, following the major reduction in FIT rates in the UK. The most pressing challenge for CRE projects is to create and implement alternative business models which will allow a reliable stream of income.

With previous research on CRE business structure only focussing on a few elements of the business model Canvas, this study goes further to explore four fundamental areas of the their business model structure: the value proposition, the customer interface, the infrastructure, and the revenue models, providing in-depth assessment of alternative and innovative business models.

In the final part of this chapter, existing local self-supply projects are analysed, and it is concluded that the integration of RE with storage could have the potential to enable RE generators to create revenue as well as providing flexibility and reliability within the entire energy system. However, the economics associated with these models remain challenging because existing research only focuses on one potential service of electricity storage. As a result, the role of storage has previously been overlooked by existing local supply model.

Therefore, this study aims to investigate and analyse whether the integration of solar PV and electricity storage can be structured to provide demand-side response services, enabling peak shaving and electricity balancing services and in turn, creating a feasible and financially viable model for community-based solar PV projects in post-subsidy conditions.

CHAPTER 3 RESEARCH DESIGN AND METHODOLOGY

This chapter outlines the research design and methodologies that have been adopted for the primary and the secondary data collection to address research questions in this thesis. The first section of this chapter provides an overview of the study area, followed by justification and rationale for selecting the research methods, presenting the sampling strategy, ethical issues and introducing the simulation software which is used to run techno-economic simulations as well as the analytical framework.

3.1 Research Focus

The focus of this thesis is to evaluate and measure the potential of CRE groups in implementing and developing projects under new policy conditions. This study employs the mixed method approach including primary data collection (survey, semi-structured interviews, and the secondary data collection (desk-based literature review and reviewing Government and official reports) to address its aim and objectives.

3.2 Summary of Research Strategy

This subsection describes the research strategy that has been adopted in this research.

The data collection strategy can be summarised in 5 stages (Figure 3.1) as listed below:

I. The first stage involves a desk-based academic and policy literature review including Journals and Government reports and official reports, to gain an in-depth understanding of key issues related to the topic and review previous research on the CRE sector.

II. The second stage comprised of, distributing the designed survey questionnaires among 364 community energy groups, community representatives and energy professionals. The survey had four main purposes:

- To empirically evaluate the recent development of CRE projects using the business model Canvas as a tool to provide an in-depth understanding of the character of the UK's CRE sector, allowing the assessment of alternative business models
- To critically analyse challenges that these projects have faced before major changes in the policy landscape.
- To investigate the impact of the curtailment of renewable support mechanisms on the development of the UK's CRE sector.
- Finally, to examine future activities that the groups could participate in under the new policy conditions and to evaluate barriers facing CRE organisations looking to develop under new policy conditions.

III. The third stage comprises semi-structured interviews to gain qualitative understanding of those projects run by respondents to the questionnaire in order to validate data gained from the survey.

IV. The fourth stage involves; using the System Advisory Model (SAM) software as a simulation tool to run a discounted cash flow analysis to critically investigate and analyse whether and how integrating of solar PV and electricity storage models can be structured to be a viable model for distributed energy system and CRE sector.

V. The last stage will be the development of a business model for Community-owned solar projects in the UK based on the sub-studies and using business model mapping.

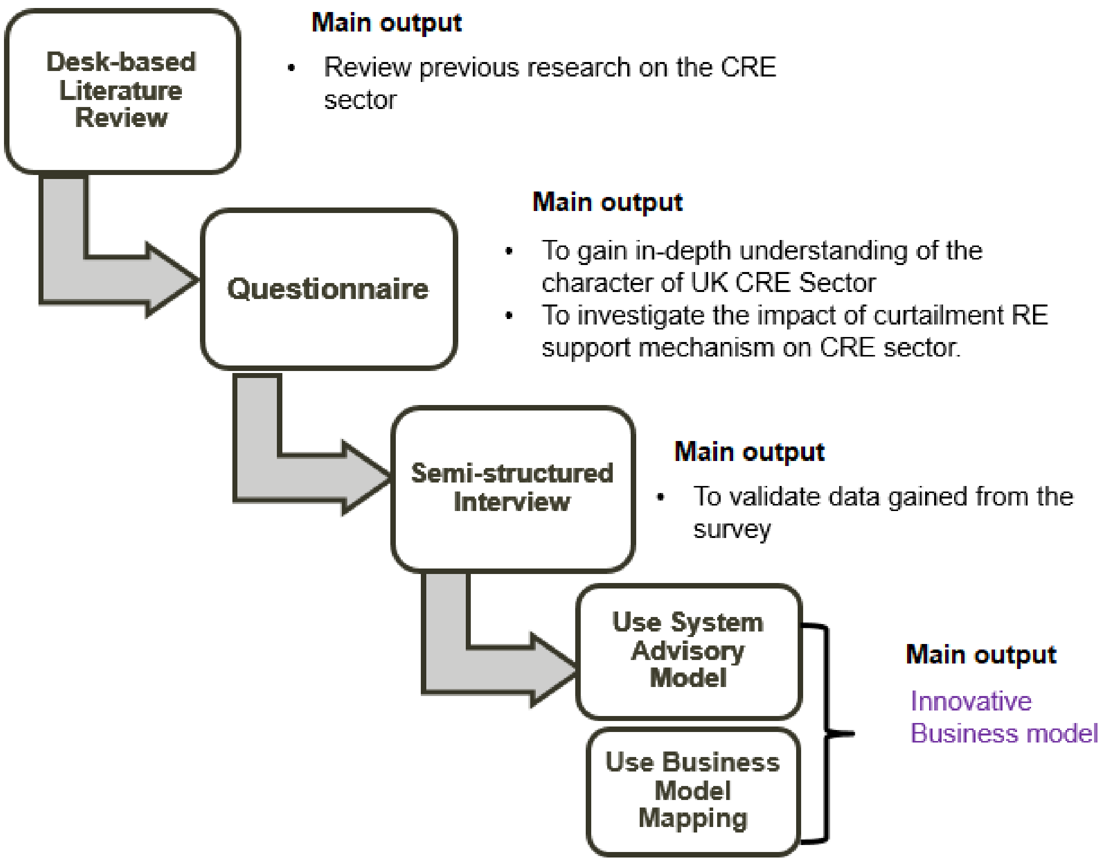

Figure 3.1: Research Strategy

3.3 Rationale for Mixed Method Approach

In this thesis, the combination of the qualitative and quantitative methodology has been used to evaluate existing CRE projects in the UK. Also, where appropriate a combination of socio-technical transitions and business model theory has been used by the researcher to explore research questions.

A combined methodology can be used to validate one form of data with another form, to transform the data for comparison or examine and explore different types of questions (Driscoll et al. 2007). This study integrated both quantitative and qualitative research method, to capture an in-depth understanding of the research topic and increase the reliability and validity of obtained findings. In many studies, the same sample or individuals provide both qualitative and quantitative data which enable the data to be validated and compared easily (Driscoll et al. 2007; Cronholm and Hjalmarsson, 2011).

As outlined in Figure 3.2 the sequential mixed method has been employed in this study to enable the researcher to employ a flexible data collocation strategy involving two data collection phases including quantitative (survey) and qualitative (semi-structured interviews).

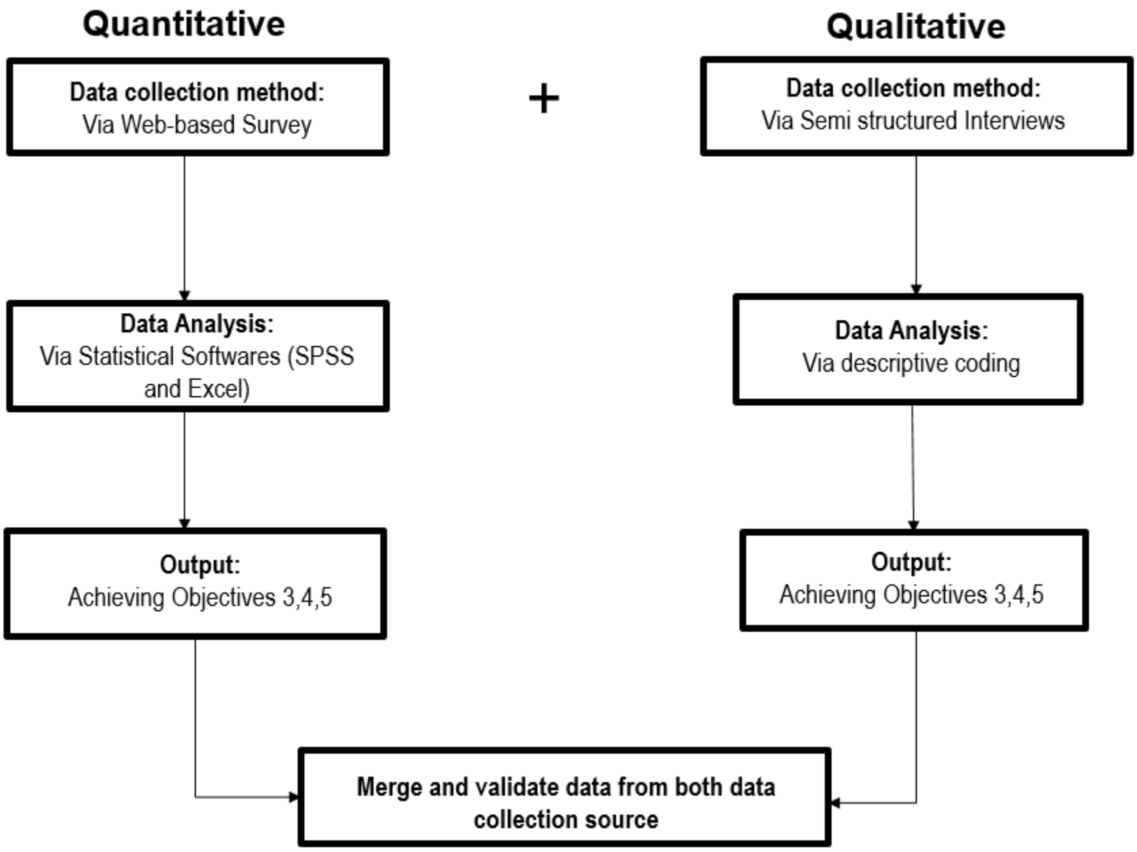

Figure 3.2 : Flow Chart of Sequential Mixed Method Data Collection

In this method collected data in one phase contributes to collected data in a next stage. Generally, the collected data in sequential design provides more data and validate results from the earlier stage of research (Driscoll et al., 2007).

Glasow (2005), defined the survey questionnaire as a tool for collecting data about the characteristic, action and perception of a large group of people. Using a survey questionnaire as a quantitative method is a well-established method for social science research and gaining information on knowledge and perception. However, the literature highlighted that the use of questionnaires and the importance of questionnaires have been relatively neglected by scholars in other fields (Bird,2009).

The strength of using survey questionnaires includes the capability of the survey to gather data from a large sample of the population, being inclusive of the type and number of variables that can be studied. Using questionnaires which primarily have all questions in the same format make the collected data comparable to other data set (Glasow, 2005; Bird 2009). However, beside the above advantages of using questionnaire it might, have some weaknesses, which can include; it cannot provide precise measurement, and respondents may not provide the whole picture of the situation (Glasow, 2005).

3.4 Data Collection Methods

This section provides an overview of the data collection methods that have been adopted to collect and validate data for this thesis.

3.4.1 Method of Literature Collection

An extensive literature review was conducted to gain a profound understanding of the UK's existing CRE projects and their characteristics and to evaluate factors that have played a role in the development and failure of current CRE projects across the UK. The literature review was conducted using academic journals including Energy Policy, Energy Research and Social Science, Cleaner Production and Government reports and official reports (such as BEIS, DECC and IEA) were used to search for relevant publications. To make sure the research was up to date with the current with the current policies and data, alerts were set in Mendeley to get notification on recent publications. The following keywords below were used in search for relevant publications.

All in titles

- Community Energy
- Community renewable energy
- Community-led energy
- Grassroot innovations
- Civil society
- Renewable energy
- Cooperatives
- Community ownership model
- Community ownership
- Innovation policy
- Business model
- Business model innovation
- Transition management
- Energy transition
- Sustainable development
- Sustainable energy transition

Finally, references which were cited in the published literature were investigated. CHAPTER 2 includes the outcome of this literature review.

3.4.2 Questionnaire, Design and Validation

In order to get a representative response rate in this study, a pilot study has not been chosen due to the small size of the CRE sector. Instead, the questionnaire was validated by a team of experts in the CRE sector who specialise in developing and managing CRE projects. The purpose of the questionnaire was to capture the research topic and questions and were thoroughly examined by one of the CRE groups representative including South East London Community Energy (SELCE) and agreed upon by both the research team and CRE groups representatives.

A relatively concise questionnaire was designed to collect data in order to increase the response rate. The designed questionnaires comprised 22 questions with both closed and open-ended questions to gather information on the business model structure of community energy groups, placing emphasis on CRE projects (the questionnaire can be found in Appendix B). Mixing the use of survey questionnaires with semi-structured interviews was selected to gain a qualitative understanding of CRE projects, in the UK. However, the main purpose of conducting semi-structured interviews was validation and triangulation of the collected data from questionnaire survey.

3.4.3 Questionnaire Sampling Method

The quantitative method involves applying statistical analysis to a sample which relies on the collected inventory of CRE projects across the UK. A web-based survey of community energy groups was undertaken between August and October 2016. This involved compiling a list of relevant community energy groups and organisations in the UK from web-based searches, predominantly from regional network organisations' lists of members (Community Energy England, Community Energy Scotland, Community Energy Wales, Bristol Energy Network, Low Carbon Hub and Northern Ireland Community Energy Co-operative). The main focus of the study were community energy groups, community representatives and energy professionals involved in RE generation. We identified around 430 community energy organisations in total, of which over 175 were located in England and Wales, around 250 in Scotland, and over 10 in Northern Ireland. However, according to the previous study conducted by Seyfang et al. (2013), in 2011 there were over 500 CRE projects in the UK. Furthermore, with rapid growth in this sector in recent years, it is unlikely that we have successfully identified all existing CRE projects in the UK.

It was not possible to access contact details for all of the identified organisations and consequently, web-based questionnaires were only distributed amongst 364 community energy organisations in the UK. Each group was approached at least twice to participate in the online survey and in total 92 responses were received. Having removed those responses which provided insufficient data relevant to our study, the final total response came to 72 organisations (20% response rate), with in total 502 RE sites/projects. The results were compared and triangulated with previous related studies for even though it targeted communities who were involved in RE projects rather than the whole sector itself and it appeared to be representative. Other surveys that have been conducted include Seyfang et al. (2013) who conducted a survey of the whole CRE sector, focusing on networking activities and characteristics of community-based energy projects (who they are, what they are doing), in this case the final total responses was 190. Similarly, in June 2013 the Department of Energy & Climate Change carried out a study to provide sufficient evidence for the upcoming Community Energy Strategy and gathered 157 responses in its final sample (DECC, 2014a). In October 2015, Community Energy England conducted a survey among its members to investigate the impact of announcement of FIT on the CRE projects; and a total of 80 responses were received (Bridge and Fenna, 2015).

Once the data was collected the Statistical software package (SPSS) and excel were used to analyse quantitative collected data.

3.4.4 Semi-Structured Interviews

Seven semi-structured interviews were also conducted between November 2016 and June 2017 among the CRE groups and the community representatives to validate the collected data from the online questionnaires. These interviews were conducted over the phone or were face to face Interviews. Potential interviewees were selected from survey respondents who had agreed to participate in semi-structured interviews in their survey responses and also based on the size of their organisations and the status of their projects (for example one of our interviewees was Chase Community-owned solar which has 314 community-owned solar projects). The interviewees included members of the CRE organisation directory board and mainly CEOs of organisations the semi structured-interview questions can be found in APPENDIX D and E. All interviews were transcribed and analysed via descriptive coding.

3.4.5 Ethics Issues

For ethical and confidentiality reasons, the survey and the interview respondents are anonymised, although in some cases the name of related organisations is provided. All the survey and the interview questions have been approved by the London South Bank University Ethics Committee, the approval letter can be found in appendices section (APPENDIX A).

Before each interview, the interviewee(s) were provided with the interview questions and a consent form stating the aim and objectives of the study, the anonymisation process, data storage analysis procedure and a brief on their right in interviews which included their right to stop and cancel the recording at any time during the interview also to request the transcript for review and make changes if necessary (See APPENDIX C).

3.5 Analytical Framework and Research Tool

This section will give an overview of the analytical framework which has been used to qualitatively analyse the business structure of existing CRE projects also, to develop an innovative potential future business model. This section also goes further to introduce the System Advisor Model simulation software which has been employed to run a techno-economic simulation to investigate the feasibility of combining electricity storage and solar PV as a viable business model.

3.5.1 Business Model Canvas as an Analytical Framework

The application of an analytical framework enables the researcher to structure the empirical investigation and helps in the process of interpreting and analysing subsequent empirical data (Smyth, 2004).

In this research the revised Osterwalder and Pigneur (2010) 9 blocks model Canvas was used to critically evaluate the character and the business structure of the existing CRE projects in the UK and to develop an innovative potential future business model. This business model Canvas, is the most comprehensive business characterisation framework and as previously mentioned in Section 2.8 in literature review has been employed by many scholars in the field including (Aslani and Mohaghar, 2013; Johnson and Suskewicz, 2009; Osterwalder, 2004; Richter, 2011) to characterise RE projects. Figure 3.3 outlines the 9 blocks business model Canvas in detail including:

Value proposition: it focuses on the economic return of a product or service offered by a firm (Bocken et al. 2014).

The customer interface: refers to the communication between a company and its target market, and the types of relationships that can be established with this particular customer segment.

Customer segments: refers to the group of people or organisation which the company aim to approach and serve.

Customer relationship: refer to the types of relationship which a company establishes to keep the specific customer segment.

Channels: this refers to the form of approach and communication with the customer segment.

The infrastructure: this aspect of the business model takes into consideration the ways that a firm can capture value and earn revenue through the services and goods it provides (Bocken et al., 2014).

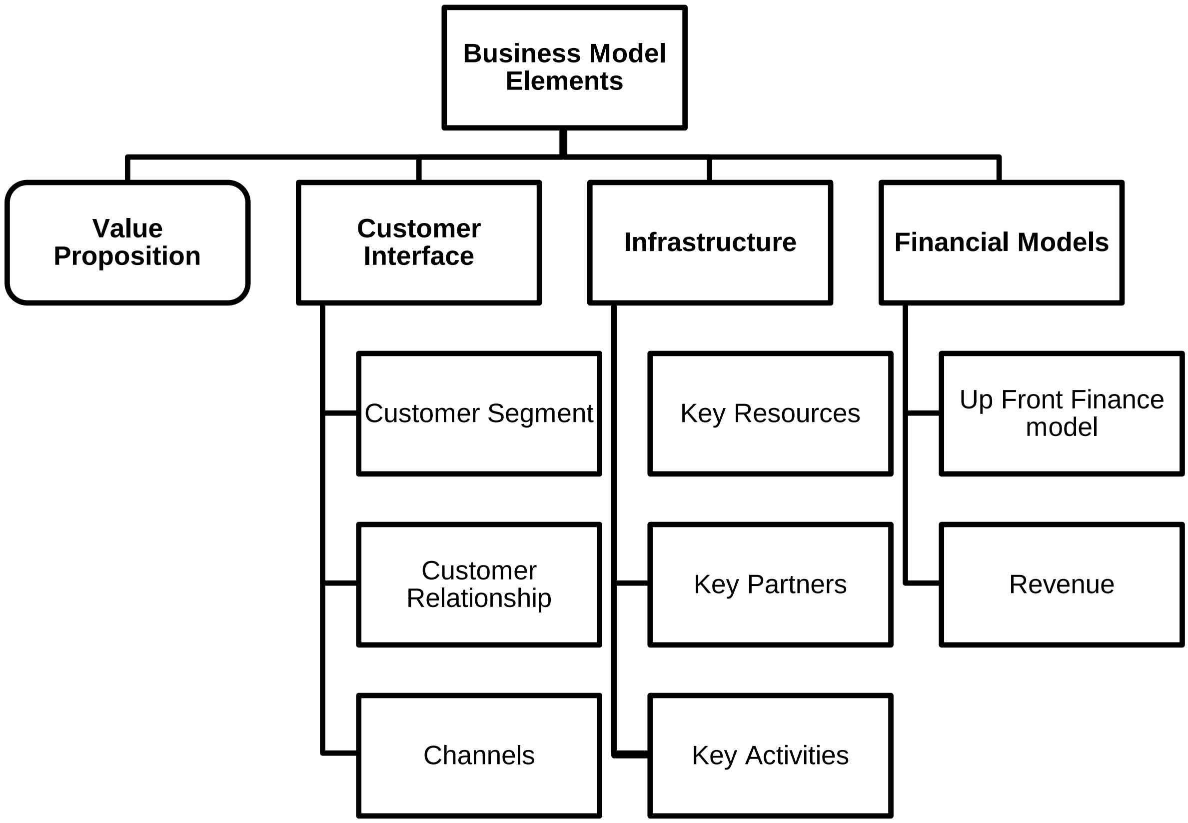

Figure 3.3 Business Elements of the Business Model Canvas,(Osterwalder and Pigneur, 2005; Osterwalder and Pigneur, 2010).

Key resources: refers to the assets and resources required to offer and deliver services to the customer segment.

Key activities: Type of activities that a company involved need to provide services to the customer segment.

Key partners: refers to the suppliers and partners supporting the company business model performance.

The final element, the revenue model, explores the potential income that can be generated from a business as well as the cost involved its operation.

Some concerns have been raised about the suitability of the business model for the empirical investigation. However, it has been argued by Hannon (2012) that employing the business model Canvas can provide a detailed picture of both the character and mechanics of a particular business model since the framework consists of sub-questions and sub classification for each element. This means it can be easily applied to collect and analyse data from the firm by using methods such as a semi-structured interviews and surveys.

3.5.2 Simulation, Using System Advisor Model (SAM) Software

Analysing the results from the questionnaires and semi-structured interviews provided a profound understanding of the CRE sector's existing business models and allowed the evaluation and investigation of an alternative business model that CRE projects can deploy for the future development. Based on these sub-studies Solar PV combined with battery storage has been identified as having the most potential, for community based solar PV system measured by available resources and the current UK regulations.

Several simulation tools were enlisted (including HOMER and RETscreen) and considered for simulation to analyse and investigate how integrating of Solar PV and electricity storage models can be structured to form a business model in post-subsidy conditions. SAM is a performance and financial model developed by the USA National Renewable Energy Laboratories (NREL) in collaboration with Sandia National Laboratories in 2005 (National Renewable Energy Laboratory, 2017). SAM as a simulation tool has been carefully chosen to critically analyse the integration of solar PV and electricity storage. To investigate the best potential alternative business case, different sizes of PV array and battery storage systems with different storage operating modes have been simulated under different economic conditions.

SAM software is designed to facilitate decision making for people who are involved in the RE industry including financial and policy analyst, project managers, and researchers. SAM software was released in 2007 for public use. Since, its public release, more than 35,000 people representing academic researchers and manufacturers have downloaded the software (National Renewable Energy Laboratory, 2017).

3.5.3 Rationale of Using SAM over RETScreen and HOMER

RETScreen is the RE technology management software in the form of excel spreadsheets and financial indicators which is designed for calculating a large number of valuable financial indicators. The main shortcomings of using RETScreen is that the input for solar radiation doesn’t consider daily load and take RE fluctuation into account (Lai and Mcculloch, 2017). Conversely, SAM software considers and supports sub-hourly simulations and operates with weather data up to one minute intervals to estimate solar generation (Gilman, 2014).

HOMER is an optimisation software package which is designed to simulate different types of RE based on NPV and it uses of sensitivity analysis with different sizes of solar PV and storage to determine the optimal size of the system.

Table 3.1 Summary of Rationale of Using SAM over RETScreen and HOMER

Name of Software	Range of Financial Performance Indicators	Considers Daily Load and RE Fluctuation	Cost of Licensing and Availability	Black Box Code Utilisation
System Advisory Model	Yes	Yes	Free	No
RETScreen Expert	No	No	Requires Subscription Fee	Yes
Homer	Yes	Yes	Requires Subscription Fee	Yes

However, the drawback of HOMER is that it requires significant computations due to a large number of cases required to be computed. It is also a Black Box code utilisation which means that the methodology and algorithm used for cost calculations are unknown (Lai and Mcculloch, 2017). In comparison, the SAM software methodology and algorithms used for cost calculations and system design are known and accessible (Table 3.1).

3.5.4 Techno-Economic Simulation of Integrating Solar PV and Storage in SAM

Figure 3.4 shows the overview of employing SAM as a simulation tool to run a techno-economic analysis of integrating of solar PV and electricity storage and to investigate how these can be structured to be a viable business model for distributed energy systems and the CRE sector.

In order to run a simulation inputs; including weather data and solar irradiation of the project location, taken from National Renewable Energy Laboratory (2005) libraries were included in the model. Technical specification systems (e.g. project size, storage durations) were modelled and were included. Financial parameters (e.g. interest rate, discount rate, loan period and cost of the system) gained from the semi-structured interviews and literature review were also inputted.

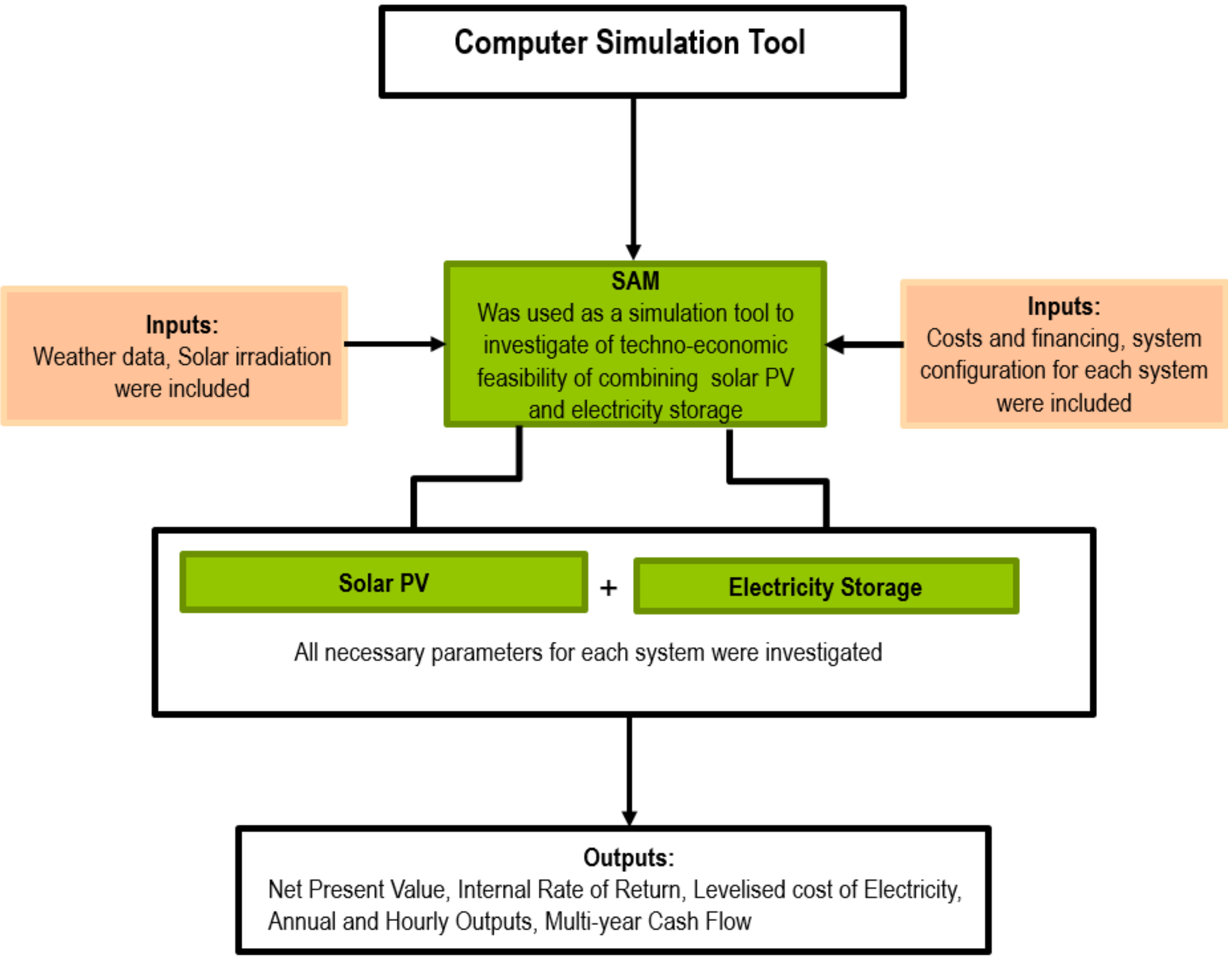

Figure 3.4 Techno-Economic Simulation of Integrating Solar PV and Storage in SAM

The financial models were run based on the retail electricity price for non-domestic buildings with private ownership (Scenario 1 and Scenario 2, CHAPTER 6). Under this model, the investment profit is calculated based on electricity bill savings, and simulations were run based on two financing options namely cash and loan.

For community-owned projects which generate revenue by selling electricity to host buildings through a Power Purchase Agreement (PPA), the solar PV commercial model which uses PPA rates has been used for financial analyses. This model allows the investigation of the financial viability of combining solar PV and storage in a non-domestic building for community-owned projects (See Scenario 3, CHAPTER 6). Under this model, the software assumes that the generator sells electricity through PPA.

The simulations have been run over the lifetime of the project (15 years); these simulations were run based on hour by hour calculation of solar PV electric outputs and hour by hour of building electricity consumption. These results contain the following financial performance indicators:

- Multi Year Annual cash flow and financial metrics
- Revenue from selling electricity and incentives payments
- Projects and partner IRR (for PPA projects)
- Levelized cost of electricity
- Electricity bill with and without the system (Revenue)
- After-tax NPV (NPV)
- Payback periods

3.6 Conclusion

This chapter provided an overview of the research methods that have been used to collect data. It also gave an overview of the research tool and analytical framework which have been employed for the data analysis. The rationale for using these research methods and analytical frameworks has also been outlined.

The following chapter will present the results which have been collected and analysed by the methodology explained in detail in this chapter.

CHAPTER 4 KEY FINDINGS PART I: AN OVERVIEW OF EXISTING UK'S CRE PROJECTS BEFORE RE POLICY CHANGES (1999 AND 2016)

4.1 Introduction

This chapter presents the first part of empirical data taken from the survey and semi-structured interviews conducted in this study which uses the business model as a tool to provide an overview of the recent development UK's community-led energy projects. In order to build alternative business models for the future development of CRE projects in post-subsidy conditions, insight must be gained from existing CRE projects, and an in-depth understanding of their business structures is essential. Therefore, this study uses the business model research tool to map and explore the different business elements of existing CRE projects. This chapter goes further to evaluate the key economic and socio-technical factors that contribute to the success of the CRE sector, and identify the challenges that the sector encountered between 1999 and 2016.

This chapter overall has three main purposes:

1. To provide an overview of development of the UK's CRE sector between 1999 and 2016.
2. To map and explore different business elements of existing CRE projects.
3. To critically analyses the key success factors of CRE projects, as well as the challenges that the sector encountered.

The following section presents the results of the first part of the survey and semi-structured interviews.

4.2 Overview of the Development of the UK's CRE Sector between 1999 and 2016

As illustrated in Figure 4.1, the establishment of CRE projects prior to 1999 was very limited. This can be explained by the lack of policy surrounding localised energy generation in the 1990s. This study shows that organisations established in this period predominately generated renewable energy as a side activity and more often, for self-consumption. The UK first RE support mechanism was the Non-Fossil Fuel Obligation (NFFO), introduced in 1990 to support the generation of nuclear and renewable energy in the UK. However, the last three rounds of NFFO only provided support for small-scale wind projects.

As Figure 4.1 presents, the growth of CRE projects between 2000 and 2008 was slow, but began to rapidly increase in 2009. Since 2000, community energy activity in the UK has been supported by the Government through various grant programmes (Walker et al., 2007).

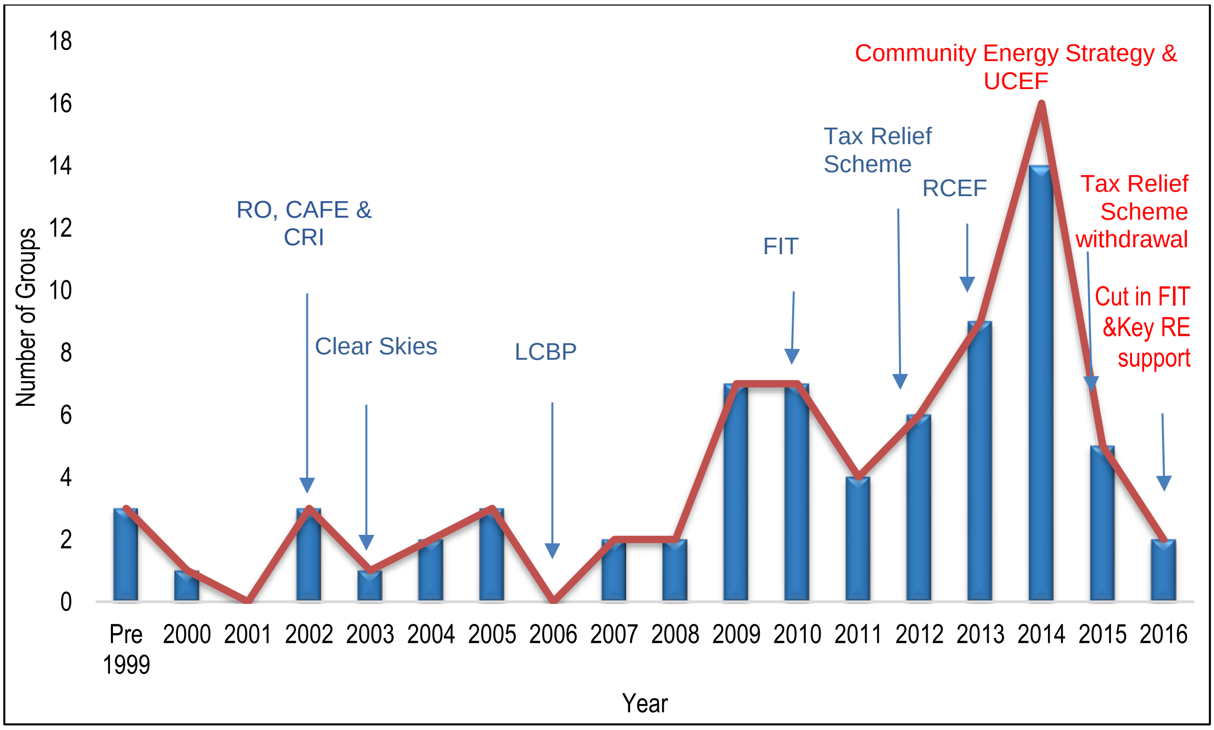

Figure 4.1 Impact of the UK's Government Support Mechanisms on the Growth of CRE Projects between 1999 and 2016

As Table 4.1 shows the first funding programme, Community Action for Energy (CAfE), was funded by the Department for Environment, Food and Rural Affairs (DEFRA) and was launched in 2002 with the aim of providing support and advice, and increasing networking opportunities for communities (Walker et al., 2007). The Renewable Obligation (RO) trading scheme was introduced in 2002, which was originally limited to large-scale RE generation, but in 2004 it was extended to projects with total installation between 50kW and 5MW.

The Clear Skies of 2003 was launched by the Department of Trade and Industry (DTI) to provide financial support for small-scale CRE projects in the UK. This was replaced by the Low Carbon Buildings Programme (LCBP) in 2006, which had two different funding streams for the residential sector and the public and charitable sectors (Martiskainen, 2014). The LCBP provided approximately £131 million worth of funds for around 20,000 projects in the UK. The introduction of the Feed-In-Tariff (FIT) later replaced the LCBP (Martiskainen, 2014).

The slow growth of CRE projects in the UK between 2000 and 2009 can be explained by their extensive dependency on grant funding. This limited the uptake of CRE projects to a certain extent, as not all projects were successful enough to receive grants in the UK's competitive energy market (Nolden, 2013a). Although not easily accessible to all organisations, the grant has often been cited in literature as a secure and stable approach towards developing RE projects (DECC, 2014a; Nolden, 2013a).

As indicated in Figure 4.1, the CRE sector saw significant growth between 2011 and 2015, and a rapid decrease in 2016. Over half of the respondents within the survey conducted (57%) established their projects between 2011 and 2016. As discussed in CHAPTER 2 (section 2.5.2), since 2010 several policies have been introduced which explicitly aim to provide support for developing CRE projects in different regions across the UK (See Table 2.2 in CHAPTER 2).

Table 4.1 A Summary of CRE Funding Between 2000 and 2010, Walker et al. 2007; Gubbins 2010

Title	Period	Aim	Policy Target	Total Funding £
Renewable energy Obligation (RO) Scheme	2002-March 2017	To support RE development	Above 5 MW projects extended to between 50kW- and 5MW in 2004	N/A
Community Action for Energy (CAFE)	2002-2011	To increase networking opportunities and provide support and advice for communities	Energy efficiency measures and related RE for communities	N/A
Community Renewable Initiatives (CRI)	2002-2007	Financial support for small-scale RE generation	Solar roofs, biomass and wood heat, wind turbines, farm waste scheme	N/A
Clear Skies	2003-2006	To give households and communities and opportunity of benefiting from RE	All RE sources	£12.5 million
Low Carbon Building Programme (LCBP)	2006-2010	Replaced Clear Skies	All RE sources	£131 million

In addition to these policies, in 2010 the UK incentive scheme for promoting RE changed from capital funds to revenue payment, which included the FIT and the RHI, and created a viable income for CRE projects (Gubbins, 2010). Notably, 20% of all existing CRE groups were established in 2014, which may be explained by the introduction of both the Urban Community Energy Funds (UCEF) in November 2014, and the Community Energy Strategy in January 2014. The rapid decline in 2016 in the establishment of new organisations may be a direct result of the curtailment of FIT scheme. In the second half of 2015, the Government announced a dramatic cut in the FIT generation, which came into effect in January 2016 (the scheme was closed between 15th January 2016 and 8th February 2016) with periodic degression (See Table 2.2 Overview of FIT Reductions in CHAPTER 2).

4.3 Characteristics of CRE Groups in the Study

The survey respondents came from a wide range of organisations involved in community energy activities, including community energy organisations (60%), voluntary/informal associations (15%), intermediaries of community energy projects (10%), networks of local energy projects, local authorities, councils involved in community energy projects (1%), and several other groups including existing cooperatives, community buildings, and groups which did not provide sufficient information about their organisations (14%). Once again, our findings revealed that the majority of the groups originated from civic and local actors. Furthermore, community energy was the main business activity for the vast majority of respondents, at 72%.

As, shown in Figure 4.2, the majority of respondents came from South East England (22%), Scotland (14%), Wales (14%), South West England (13%), North West England (12%), London (7%).

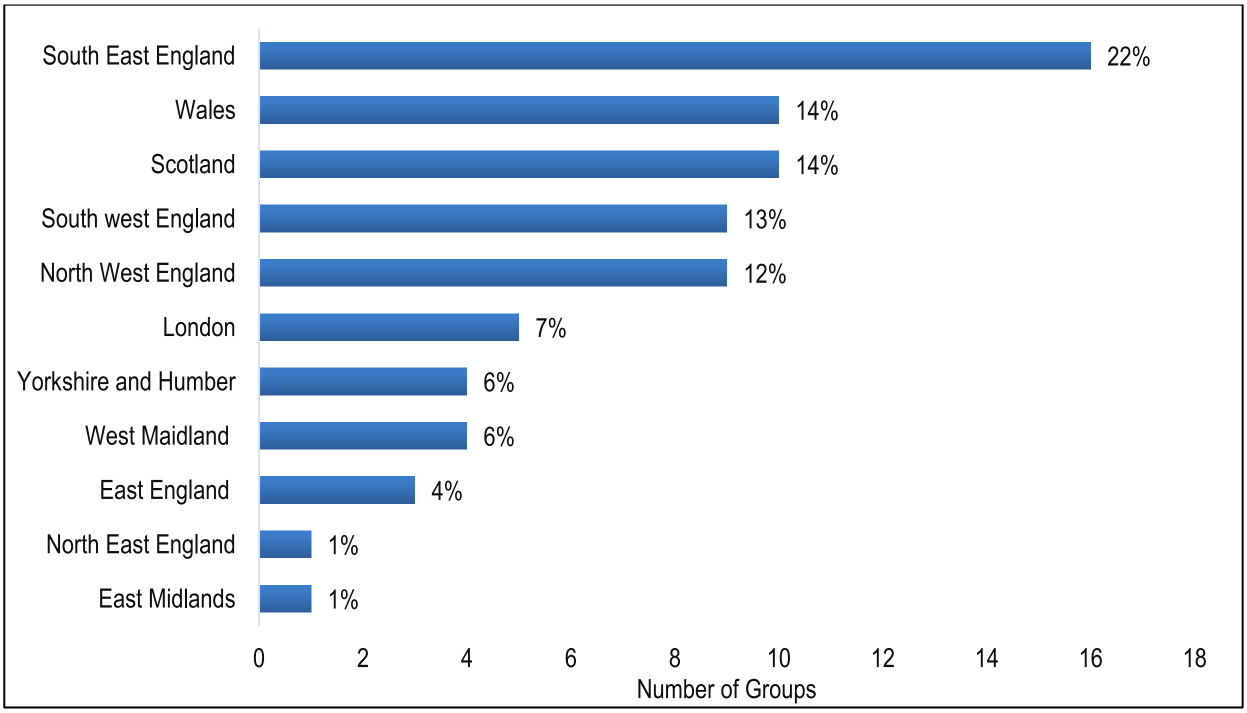

Figure 4.2 Regions of CRE Groups in the Study

The most dominant technology in Southeast England and Southwest England was Solar PV projects Figure 4.3. In Wales Hydro projects and energy saving projects dominated and in Scotland, the most common technology was Hydro.

Figure 4.3 Geographical Location of Community Energy Projects under the Study

4.3.1 Organisatioanl Structure

Our survey findings revealed again that; the UK's CRE market segment is regionally diverse in terms of legal structure and business model. The majority of CRE organisations that took part in our study use the Community Benefit Society (CBS) legal structure, accounting for 26% of those in South East England. Following this, the Industrial Provident Society (IPS) accounted for the legal structure of 20% of respondents and was most prominent in Scotland and North-West England. In South East England, in addition to CBS and IPS, cooperatives were one of the most widely used legal structures. In Wales, in addition to CBS and IPS, Community Interest companies limited by guarantee were also common.

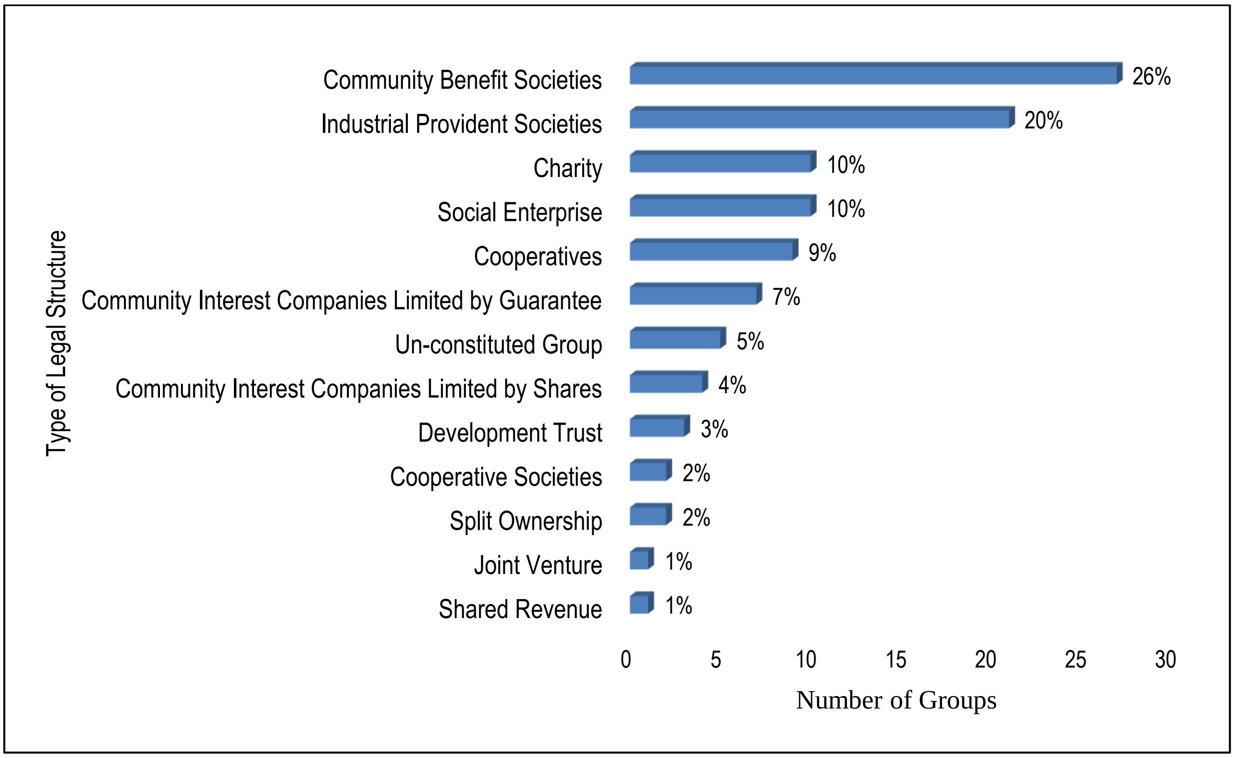

Figure 4.4 Legal Structures Groups in the Study

4.3.2 The Most Common Business Model among UK CRE Groups

This study shows that business models of CRE organisations can be classified by three groups: the community finance model, the community partnership model, and the non-energy-focused organisation.

4.3.2.1 Community Financed Business Model

Most organisations that took part in our study used a community financed business model. This model largely refers to those projects which are developed, invested in and run by members of a community and function almost entirely with the help of volunteers. Not only does this model increase cost efficiency (Huijben and Verbong, 2013), the involvement of local people in RE investment has many benefits for communities, as it strengthens local support for new energy infrastructure. Community finance business models can be deployed in different forms to fund different types of RE technology. However, one of the most common forms of energy which benefits from this model is solar PV for community buildings. Under this model, a community organisation will lease a roof or land from a community building such as schools or social housing blocks, but ownership of the technology and revenue streams (FIT) stays with the CRE organisation.

This model enables community buildings to use generated energy at a much lower price than what is available from the National Grid and save a significant amount of money. A similar study have indicated that in recent years, the amount of money saved annually by 20 different energy schemes across the UK, was £172,500 (Bridge and Fenna, 2015).

Under a community finance business model, CRE organisations work in partnership with local authorities and councils, providing an opportunity for them to install their projects on sites owned by the community. Upfront costs for these projects are financed by the investment of a member (cooperative investment, crowd sourced debenture), with additional funds coming from both grant funding and non-grant funding.

4.3.2.2 Community Partnership Model

These types of CRE projects involve a partnership between a RE developer and a CRE organisation. Commercial developers are often involved in these projects because they are interested in strengthening local support for renewable development and engaging people with the concept of RE, which helps to reduce 'Not in My Back Yard' (NIMBY) attitudes (DECC, 2014b). These projects are financed by community shares and crowd sourced debenture, with additional funds coming from banks and commercial loans. These types of projects mostly function with the help of professionals and paid employees. Amongst the groups in the study, only a few had a community partnership model. Partnership (shared ownership) can be sub-categorised into three models ; joint venture (JV), split ownership, and shared revenue arrangements (Haggett et al., 2014). In this study, we identified two groups with split ownership models followed by one group with a shared revenue model, and another with a joint venture model. Under the split ownership model, a project is split over two or more separate generation plants, one of which is owned and run by communities (Figure 4.4). The other owner, or owners, can be commercial developers or utilities

4.3.2.3 Non-energy-focused organisation

This model involves an existing community organisation, for example one belonging to a school, a church or a community centre, an environmental charity, and voluntary or informal associations which work on RE projects as a side business. This type of group usually functions as a charity or trust, and their main aim is to increase corporate social responsibility and save money by using renewable electricity or heat energy on site. The community is involved in this type of model by individuals being either a member or beneficiary of the organisation. The upfront costs of this model are often funded by charitable donations and the Government or the local authority, excluding equity or share.

4.3.3 The Morphology of CRE Projects in the Study

The following sections map and explore different business elements of existing CRE projects using the business model Canvas discussed in CHAPTER 3 section 3.5.1 as a framework. In order to gain insight from existing CRE projects and an in-depth understanding of their business structures (Table 4.2).

4.3.3.1 Value Proposition

Community business models initiated by a group of local people with bottom-up approaches and diverse aims are often divided into four main categories: economic (revenue generation, economic growth and job creation) (Hall and Roelich, 2016); social (fuel poverty reduction and social cohesion) (Walker et al., 2007; Seyfang et al., 2013); environmental; (Generating electricity/heat from RE and reducing the carbon footprint); and political (community empowerment, energy independence and local accountability) (Seyfang et al, 2013; Hall and Roelich, 2016).

Table 4.2 The Morphology of Different Types of CRE Business Models in the UK Based On (Osterwalder, 2004; Osterwalder et al., 2005)

Business Model Element	Business Model Sub-Element	Community Financed	Community Partnership Model	Non-Energy Focused Organisation
Value proposition	----	-Green Electricity/Heat from local sources - Local ownership and decision making -- Low risk financial investment offering competitive rate of return	- Local ownership and decision making - Strengthening local support for RE development - Engaging local people with the concept of RE	- Green Electricity/Heat from local sources - Reducing their bill using renewable electricity or heat on site
Customer interface	Customer segment	- Owner of the premises which the RE facility is installed - Consumer in general	Consumer in general	-Owner of the premises which the RE facility is installed
	Customer relationship	- Simple energy provider relationship	- Simple energy provider relationship	
	Channels	- Word of mouth communication - Social media/network - Community energy network organisations	-Through online investment platform (Ethex, Abundance Energy) - Social media/network	-Word of mouth communication - Social media/network
Infrastructure	Key Activities	- Multi-faceted (RE generation and Fuel poverty alleviation) - Financing distributed Solar PV for community buildings (Third party premises), partly with selling the electricity to the premises owner	RE generation	RE generation
	Key Resources	- Renewable installation including Solar PV, hydro, wind - Expert volunteers/Paid management - Regional network -Trust relationship with prospective host owner	-Renewable installation including Solar PV, hydro, wind - Regional network - Professionals /Paid employees Trust relationship with community and commercial developer	- Renewable installation including Solar PV and renewable heat (e.g. Bio mass) - Expert volunteers
	Key partner	- Local Authorities (LA) - Councils - Host owners (schools, community center)	- Commercial RE developer - Intermediaries	- Local Authorities (LA) - Councils
Financial model	Up front finance model	- Government funding schemes, - Social private loans - Local Authority (LA) funding scheme - Co-operative investment, crowd sourced debenture	-Bank loans -Commercial and social private loans -Cooperative investment, crowd sourced debenture	- National lottery - Gift/ Charitable funding - EU funding scheme - Government funding schemes, - Local Authority funding scheme - Sponsorship
	Revenue	-Public Subsidies (FIT,RHI) -Mixture of FIT/RHI & PPA	-Public Subsidies (FIT,RHI, and renewable obligation) -Mixture of FIT/RHI & PPA	- Public Subsidies (FIT,RHI) Saving on the bills

4.3.3.2 Key Activities

This study reveals the multi-faceted nature of community energy projects, for example among groups in the survey 47% engaged with different activities of community energy projects (including energy efficiency, energy generation and provide consultancy to community energy projects). 33% solely focused on energy generation followed by 20% which only focused on energy saving projects (Figure 4.5).

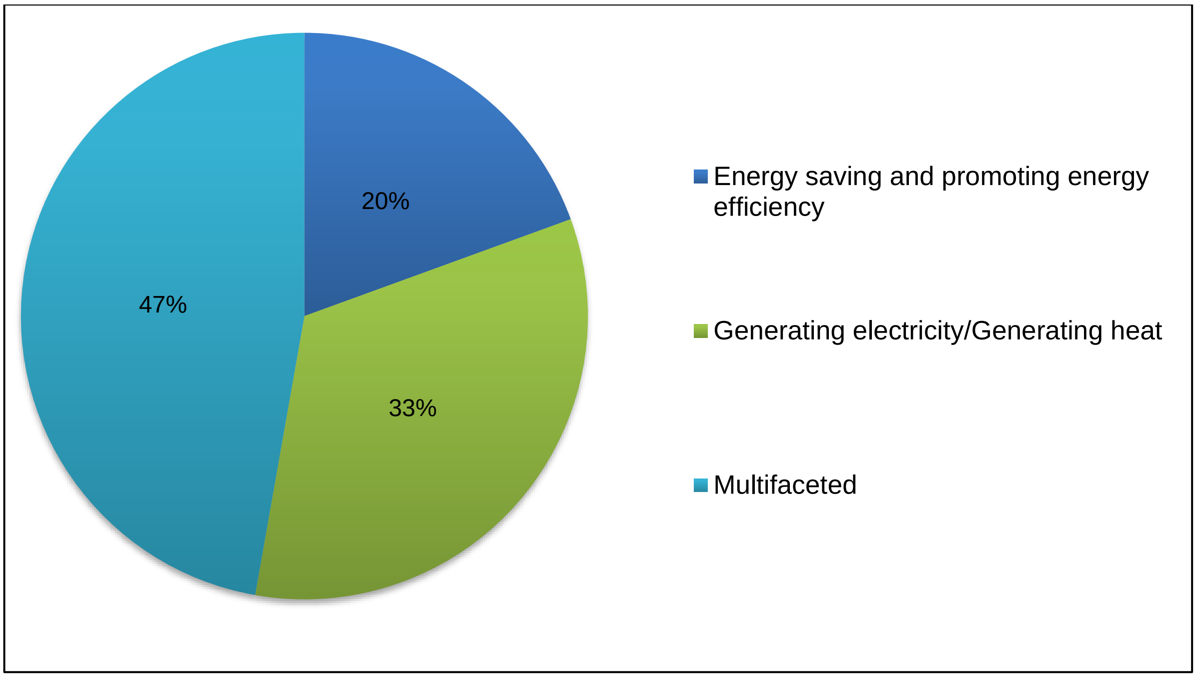

Figure 4.5 The UK's Community Energy Group Activities (Pre-2016)

4.3.3.3 Key Resources

The most common type of RE generation amongst the respondents' groups was electricity, and renewable heat was much less established.

Solar PV was the most dominant renewable technology amongst the community groups involved in energy generation, with the vast majority of them being in operational stage (Figure 4.6). The next most common type of technology was hydro, followed by onshore wind. The most dominant technology in South East and South West England was solar PV. In Wales, hydro projects and energy-saving projects dominated. Similarly, in Scotland, the most common technology was hydro. A few groups in the study were not active, including five hydro schemes, three solar PV schemes and one Anaerobic Digestion (AD) scheme. Inactive groups stated that the main reasons for their project failure was the dramatic reduction in FIT and the removal of pre-accreditation, which made their projects financially viable.

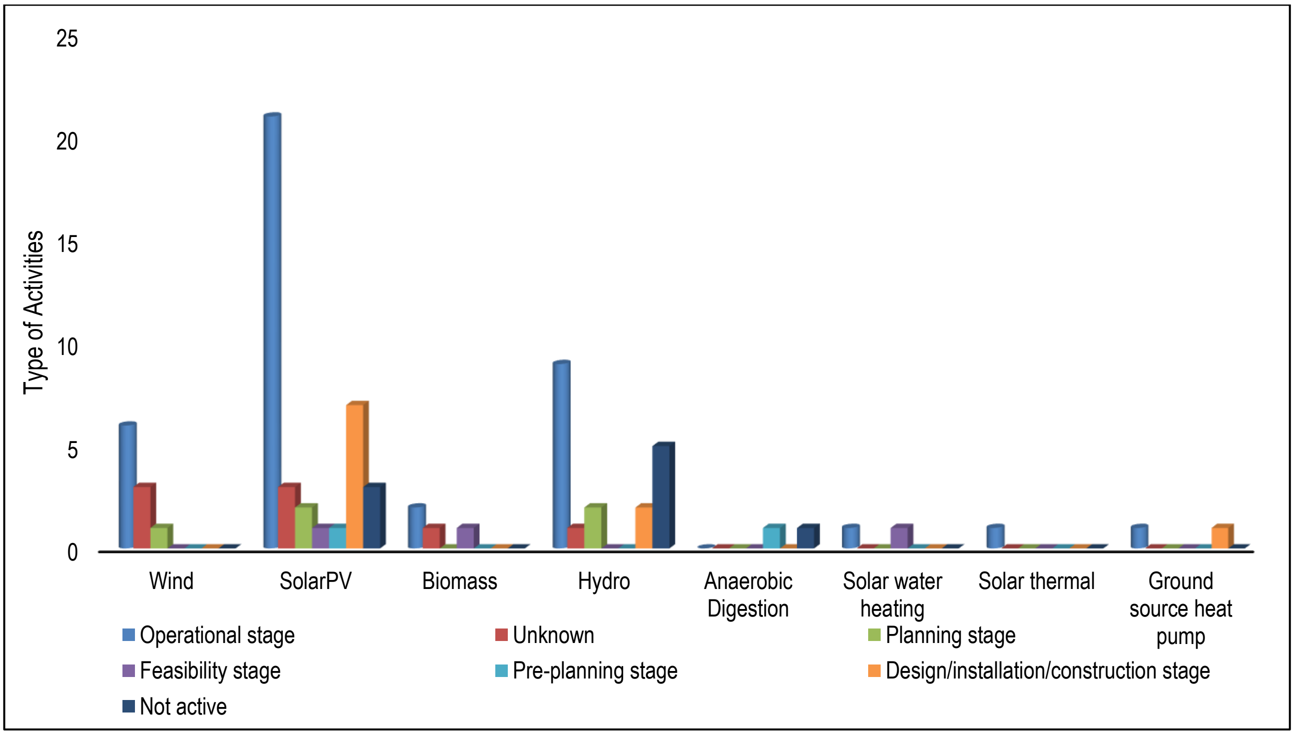

Figure 4.6 The Different Types of Technology CRE Projects, with Phases of Development

CRE projects vary dramatically in size with over half of the projects only having a total installed capacity of between 51 to 500 kW. Approximately a third of these projects are micro schemes with a total installed capacity of less than 50 kW.

The majority of CRE groups run by the respondents in this study have multiple sites, with 68% of them having between 1 and 3 sites and being in operational phase, but there were also 9 non-active sites.

This study shows that the majority (68%) of the responding CRE organisations did not have any paid employees, and they instead depended on the skills of volunteers during the setting up and development stages of various activities (Figure 4.7).

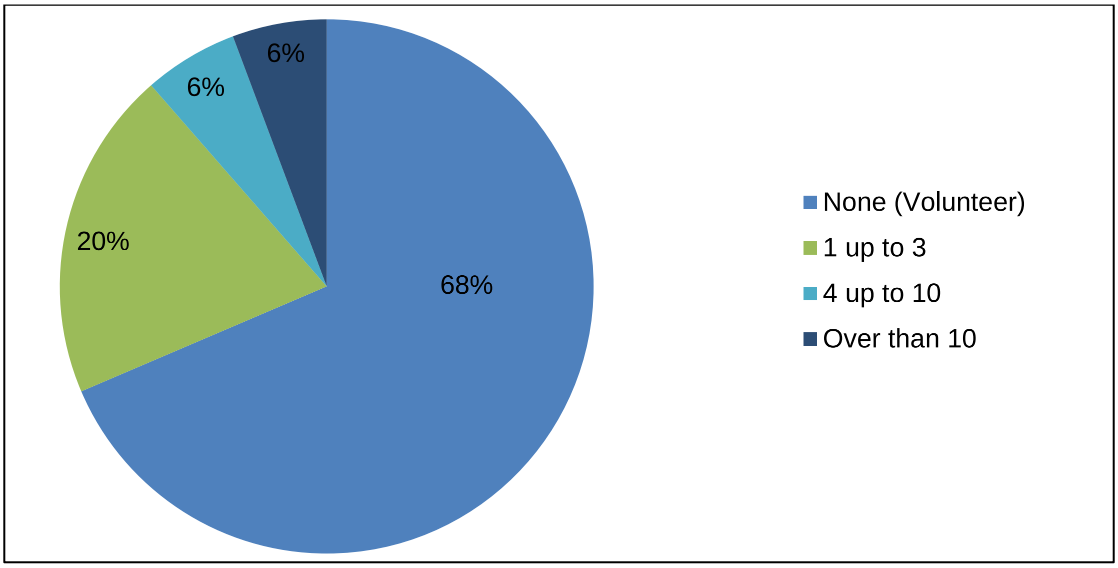

Figure 4.7 Number Of Employee of UK's Community Energy Group/ Organisation

As Figure 4.8 shows nearly half the organisations in the study (43%) had 4 up to 10 volunteer workers which indicates the small size of these organisations.

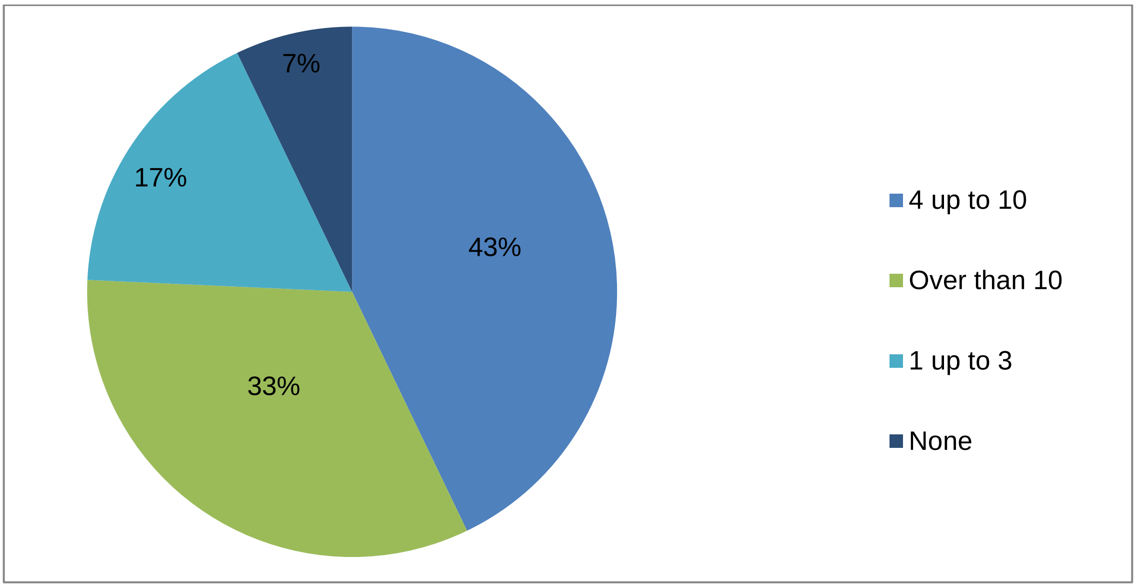

Figure 4.8 UK's Community Energy Organisations/Group Number of Volunteers

4.3.3.4 Key Partner

The results show that the majority of CRE groups which took part in the study worked together with other organisations, rather than acting completely on their own. However key partners of CRE projects are different and based on the business model they take up. For example, for in the community partnership model, CRE groups work in partnership with commercial RE developers and intermediary organisation (See Table 4.2 for other type models).

4.3.3.5 Financial Model

Historically, CRE projects have been extensively dependent on grant funding, but this dependency has limited, to some extent, the uptake of local based RE activities. Not all projects were successful enough to receive the grant in the UK's competitive energy market (Nolden, 2013a). However, the grant has often been cited in literature as a secure approach to developing RE projects (DECC, 2014a; Nolden, 2013a).

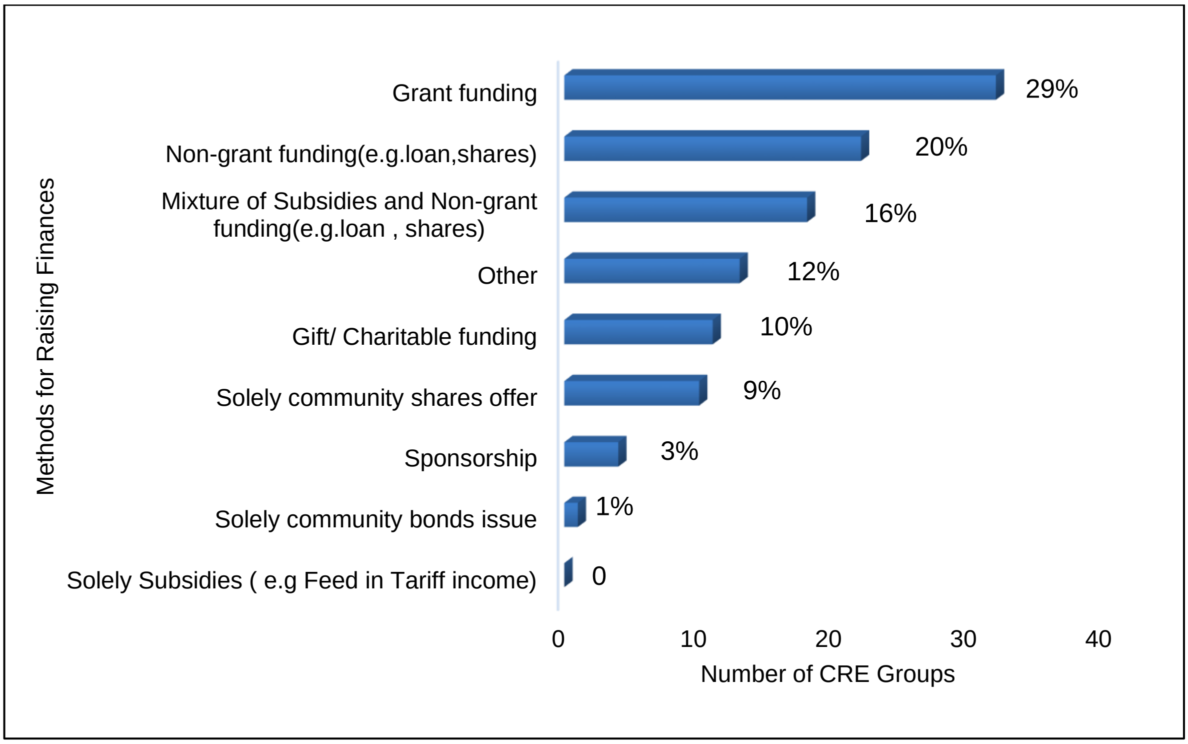

Figure 4.9 Methods for Raising Finances based on survey results

After the introduction of FIT and RHI, and the emergence of alternative sources of funding (loan, and community share), the financial viability of these projects increased and their growth was boosted (Catney et al., 2013; Nolden, 2013a). Despite this, CRE projects are generally reliant on grants and public subsidies for financial viability and repaying investors' money.

From Figure 4.9, it can be seen that 29% of community energy groups used grant funding to finance their projects, and 20% used non-grant funding, which includes community share and loans.

This study showed that CRE projects financing mixes are diverse, due to the high costs involved in the development of CRE projects. CRE groups generally combine innovative ways of fundraising from different financial contributions including citizens (through community share and crowdfunding), Government support schemes, public entities and private organisations (Rijpens et al., 2013). Usually, these groups, use different types of funding in the different phases of their projects. Walker (2008) also noted that community-led energy projects often use multiple sources to finance their projects. For example, in this study, over half of the groups who used grant funding (54%) also used other sources of funding, with some using up to 5 different sources. This study showed that these groups used government funding schemes in the development phase and feasibility phase. Only 9% of organisations solely used a community share offer to finance their projects.

As indicated in Figure 4.10, the majority of groups in this study (43%) used a Government funding scheme to finance their projects. Social or private loans were used by 17%, followed by 16% who used a local authority funding scheme. The most frequent answer in other categories was funding from European funding scheme.

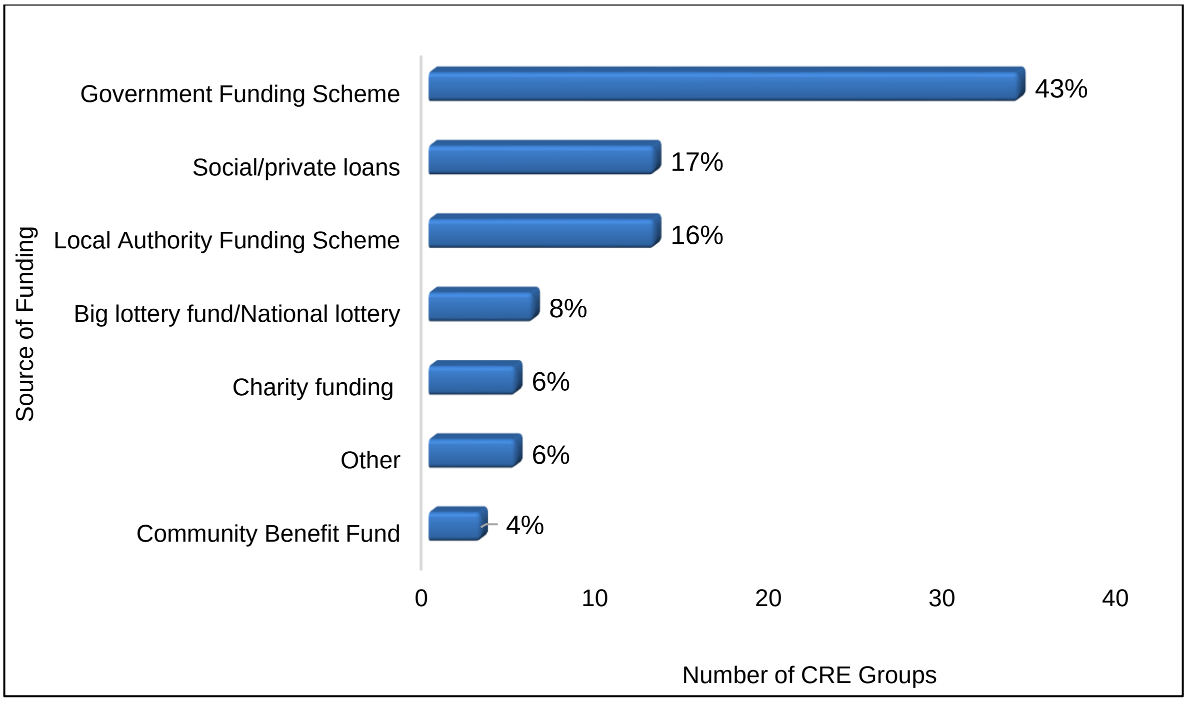

Figure 4.10 UK'S CRE Source of Funding

For 75% of respondents, their community energy projects generated income. This study shows that income for almost all organisations or projects primarily comes from public subsidies. Therefore, one of the critical challenges facing CRE projects following the FIT reduction in 2016 is to maintain a consistent stream of income which is less dependent on public subsidies and instead is created by selling heat or electricity independently. As, Figure 4.10 presents, a mixture of public subsidies (FIT and RHI) and the direct sale of electricity to site-owners or host organisations through the Power Purchase Agreement (PPA), was the main source of income for 39% of respondents. However, 25% of groups did not have any income, and these were made up of groups in the process of being set up or developed or those that had become inactive.

The mixture of public subsidies (FIT and RHI) and the direct sale of electricity in particular, provided income for rooftop solar PV technology with a community financed business model. Under this model, a community-led energy organisation leases land (or a roof) from a community building (e.g. schools or community centres) for a period of 20 years to install

RE technology. This model enables the residents of the host building to buy and use generated electricity or heat through the PPA at a lower price (typically between £0.05 and £0.07 per kWh) than the current national grid. Community energy groups operate and maintain the renewable technology, but they receive FIT/RHI generation and export income. The amount of export income depends on the energy usage pattern of the host building.

Public subsidies were the only source of income for 25% of groups in the study, in particular those which used a community-owned business model. Some groups had other commercial income (7%) or did not provide answers (4%).

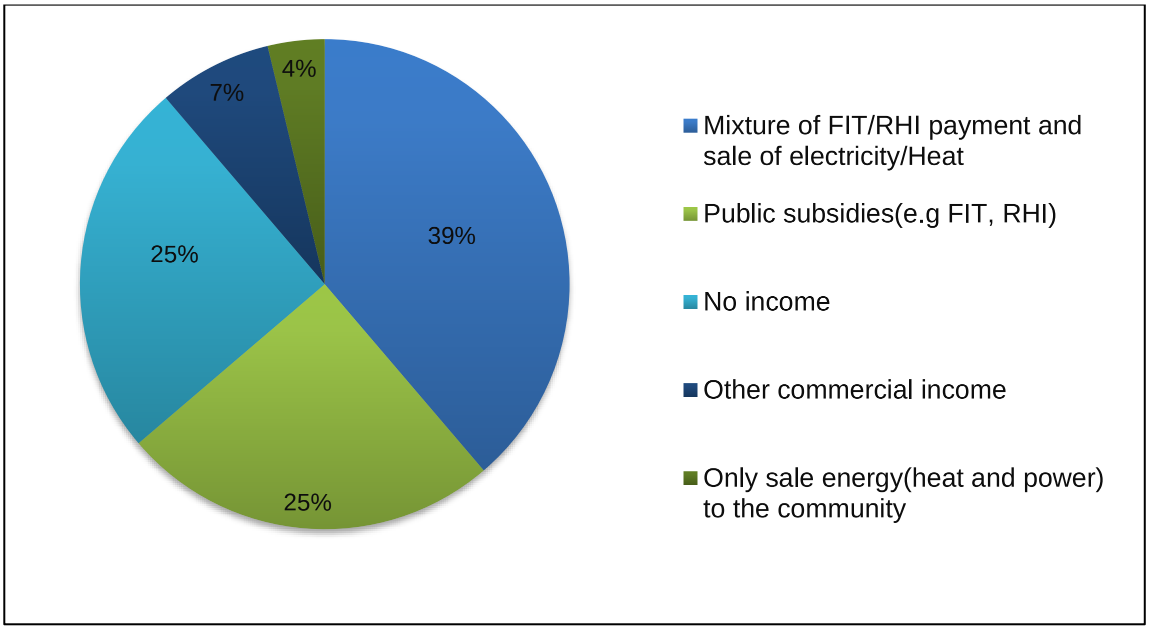

Figure 4.11: UK's CRE Projects Source of Revenue

4.4 The Main Challenges Encountered CRE Sector Pre-2016

This section evaluates the obstacles encountered by CRE projects before the reduction of renewable support mechanisms in 2016. The challenges that faced these projects were a mixture of economic and financial, institutional, and cultural and technical issues. Groups taking part in this study were given the task of rating the different obstacles they faced prior to, or during their development, on a scale of how challenging they were.

4.4.1 Economic and Financial

The results from the study show that that the major economic and financial challenges facing CRE groups before 2016 were the difficulties involved in finding viable sites, and the challenge of fundraising with a lack of consistent financial support.

As Figure 4.12 indicates, identifying viable sites for renewable energy installation was extremely challenging for 28% of groups that took part in the study. However, another 40% of respondents claimed that this was less challenging and 29% did not find it a challenge at all. [1]This hurdle was particularly problematic for rooftop solar PV projects which generated between 51 kW and 500 kW of energy. This is perhaps due to the volatile property market, the complexity of tenure, and the unstable lifespan of commercial building stock. The likelihood of a CRE business model being able to scale up a project is dependent upon a site being available to host RE technology for a period of 20 years. Therefore, for community-based solar PV projects, viable sites were more likely to be on non-domestic roofs, and sites that are owned by a single entity, due to the long-term commitment needed and the high cost of the feasibility study and legal fees.

The further investigation shows that finding viable installation sites for CRE projects was a particular challenge for those set up in London and South East England, but less challenging for solar projects which were located in Southwest England, Yorkshire and Humber. Collaboration between CRE groups and local authorities, particularly in Southwest England, has provided an opportunity for projects to install technology on locally-owned buildings, such as schools and community centres. For example, community-based solar PV projects have developed significantly in Bristol as a result of active support from Bristol City Council,

[1] The main reasons why identifying sites was less challenging for some groups has been explained in more details in the next paragraph.

and the opportunity to use their buildings for installation.

A respondent from a small-scale community-based solar organisation in England specified that in addition to all of the previous reasons, a lack of engagement within the community and residents of host buildings was one of the main difficulties in locating a viable site for installation.

“There was a range of reasons why some organisations (including schools) did not want to be part of the project... some were simply not interested in the idea of saving energy and carbon, and therefore saving on their electricity bill. Others were interested, but it was not a priority for their organisation, so they did not take the time to consider this opportunity."

While there were various sources of funding available (i.e. the Government and other commercial and social sources), this study has shown that fundraising was the second extreme challenge facing CRE groups (Figure 4.12) and 25% of respondents stated that it was an extremely challenging hurdle to overcome.

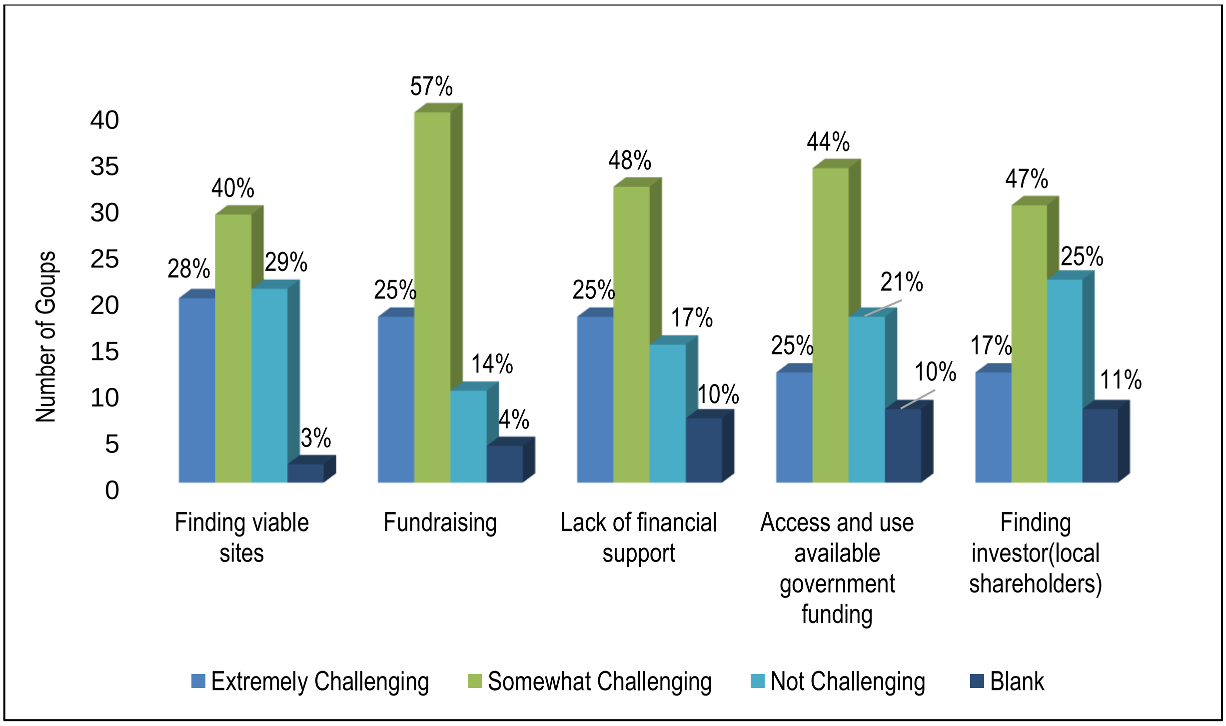

Figure 4.12: Economic and Financial Challenges Facing the UK’s CRE Groups

Potentially due to the high risk involved in taking out of a large loan to fund the project, some

CRE groups have chosen to receive community benefit funds rather than take risks involving community investments (Haggett, et al., 2014).

It has also has been pointed out by Julian and Olliver (2014) that there is a lack of faith in small projects, and therefore banks are less likely to invest in CRE projects, preferring instead to opt for sole ownership, making it a challenge for CRE groups to raise funds.

This is illustrated by a feedback from a CRE intermediary organisation located in London that said:

"*Developing our 230 kWp solar projects was more challenging than our 10 MW solar project, we started both scheme almost at the same time and finished our 10 MW earlier."*

Furthermore, the UK lacks a reliable financial support scheme, such as the likes of those which are in place in other European countries. In Germany KfW bank provides long-term lending at a 1% interest rate, which helps to reduce the risk involved in the deployment of community-based renewable energy. Simpson argues, in the UK this 'could be assigned to Green Investment Bank, but it has not been' (Simpson, 2013,pp4).

Figure 4.12 reveals that a lack of financial support during the development stages of projects was a major challenge for 25% of respondents, and somewhat challenging for nearly half. This was mainly caused by recent changes to UK RE policy, including the removal of tax incentives in November 2015, the drastic reduction in FIT rates in 2016, and also the withdrawal of Urban Community Energy Funding (UCEF) scheme in July 2016, which was notably very close to the data collection period for this study. UCEF provided funds for CRE projects to assess the technical and structural feasibility of their sites and pay for legal services to be put into place. Recent policy changes have made it very difficult for established groups, in particular solar PV and hydro organisations, to develop further projects, and virtually impossible for groups that are not yet established.

Access to available Government funding such as UCEF and Rural Community Energy Funding (RCEF) was extremely difficult to gain for 25% of groups in the study, and somewhat difficult for 44%. This was challenging in terms of bureaucracy, as the application was a complex and time-consuming procedure. However, 21% of respondents did not find it particularly challenging to access Government funding.

Figure 4.12 indicates that finding investors (raising community share) was less of a challenge for CRE groups. This is possibly due to the emergence of co-operative share offers, and crowdfunding, which all provide an opportunity for individuals to invest in local energy generation projects (Julian and Olliver, 2014). Similarly, the emergence of intermediary organisations and online investment platforms allowed CRE organisations to raise funds and community share. Further statistical analysis shows that raising community shares was relatively manageable for CRE groups that were established between 2012 and 2015, as they were able to access to the Tax Relief scheme (SEIS and EIS) which was launched in 2012. These schemes increased the profitability of projects and encouraged communities to invest money in CRE projects. However, as of 30th November 2015, CRE groups were excluded from this scheme.

4.4.2 Institutional

Another huge challenge that faced CRE groups in this study was the lack of policy support and the difficulty of gaining planning permission.

Approximately half of the respondents found the lack of structured policy support extremely challenging. In-depth statistical analysis has revealed that the majority of projects which reported that lack of policy support was the most challenging barrier they faced, were established in 2009 or 2013.

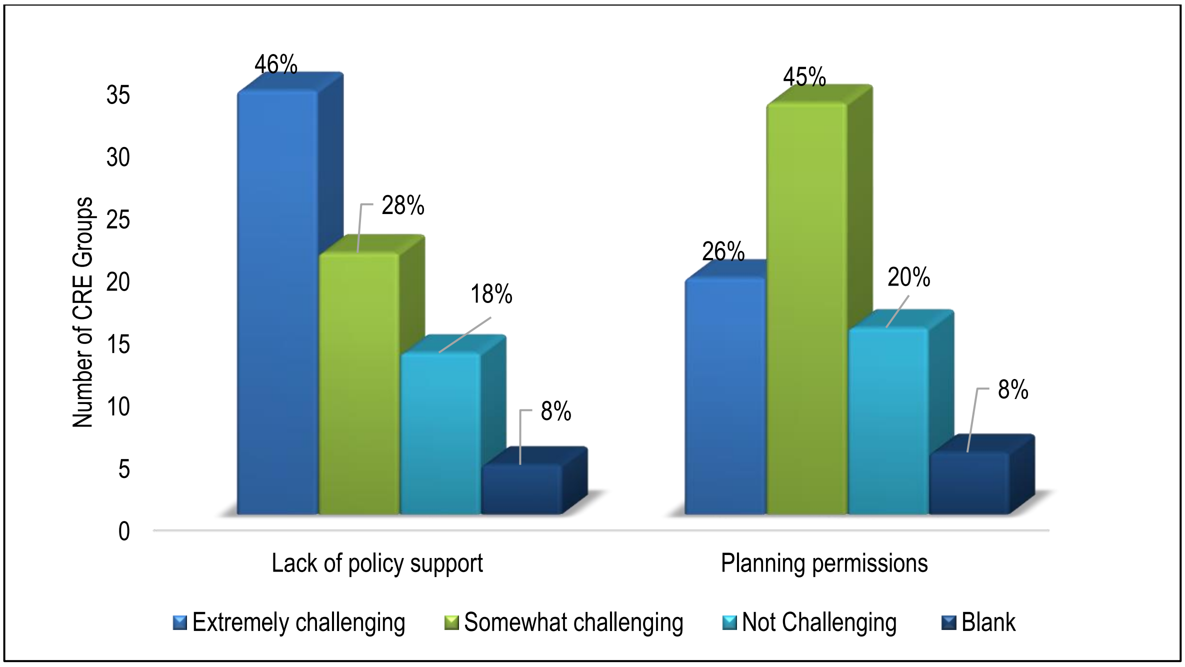

Figure 4.13: Institutional Challenges Facing the CRE Projects in this Study (pre-2016)

This can be explained by two main factors: the high grant dependency of CRE projects existing prior to the introduction of FIT in 2010, and the first reduction of FIT rates in 2012. However, projects which were established after 2014 could benefit from the Community Energy Strategy (launched in 2014 and updated in 2015) and the establishment of the Community Energy Unit which facilitated the formation of CRE projects after 2014.

Despite this, one of the respondents interviewed stated that:

"*There is no sign of updating the Community Energy Strategy after renewable energy policy changes, and the status of the community energy unit within BEIS is currently blurry.*"

Also, another of the respondents interviewed stated that:

"*Virtual abandoned community energy strategy has been restricted what community energy can do.***"**

Whilst planning permission is expected to be a less challenging process for local RE projects, this study indicates that it was extremely difficult for over a quarter of respondents, particularly for CRE projects based in Wales. Almost half of the respondents found gaining planning permission to be at least somewhat challenging. Planning permission was not expected to be a hurdle for all types of CRE projects, due to permitted development rights for renewable projects such as rooftop solar PV projects. However, the semi-structured interviews reveal that the major challenge for solar projects was in regards to leasing permission.

Planning permission for wind projects depends on the region where the wind farm is based within the UK. If the project is based in England and Scotland, certain wind turbines are permitted without planning permission, but they must be certified by the microgeneration certificate scheme (MCS). However, wind projects based in Northern Ireland and Wales require planning permission for any system (TheGreenAge Ltd, 2016).

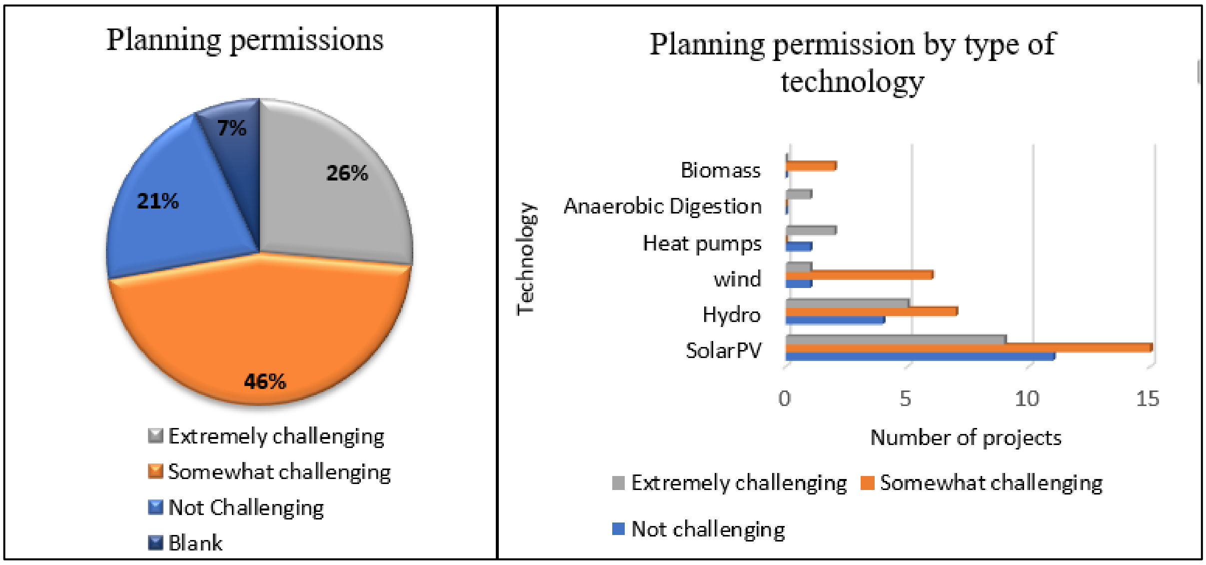

Figure 4.14 Planning Permission Challenges by Type of Technology

Figure 4.14 shows, gaining of planning permission for hydro projects proved somewhat challenging due to the requirement of an environmental licence. An environmental licence involves the assessment of potential impact on the surrounding landscape, the nature conservation and the water regime (Planningportal, 2012).

The results from the study indicate that gaining planning permission for community wind projects was not a major challenge. However, the Energy Act 2016 shifted the decision-making process for wind farms back to local planning authorities, rather than the previous Secretary of State, who originally dealt with wind farms with an energy output of over 50 MW (UK Parliament, 2016). This makes the process for large scale wind farm more difficult as they may face local opposition.

4.4.3 Cultural

Engaging the community with local energy generation is a vital to the success of any CRE project. Community engagement allows trust to build between individuals and the project itself, which in turn will help organisations source volunteers to participate in CRE projects.

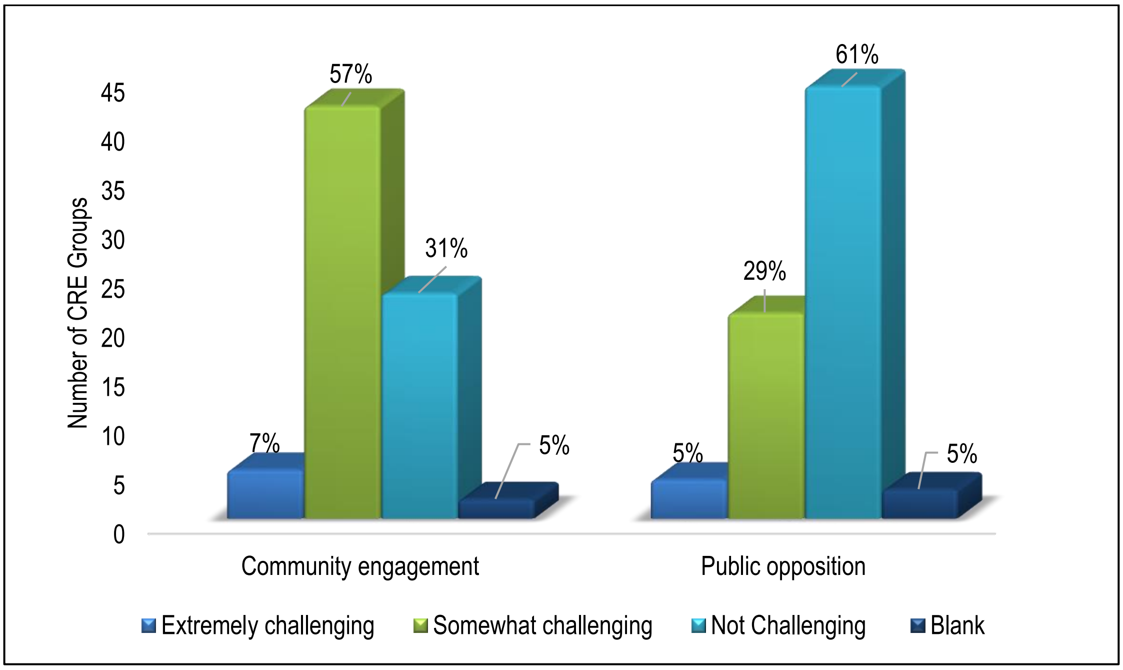

Figure 4.15 Cultural Challenges Faced CRE Pin the UK before 2016

Over half of the respondents found it challenging to engage with the local community, as the process of building trust in a CRE project can take a long time. However, 31% of groups that participated in the study did not find this an issue.

Figure 4.15 shows, 61% of groups in the study did not experience any public opposition in the first stages of their projects' development and only 29% found it challenging to engage the local community. This shows that CRE projects in the UK face less public opposition compared to other types of renewable projects and indicates that having ownership and responsibility for renewable energy generation can increase trust in local energy projects and reduce opposition.

4.4.4 Technical

The main technical challenge that faced UK CRE projects was the issue of network connection. This challenge was recorded as a major obstacle for 19% of groups in the study, and in particular for wind and hydro energy projects. Network connection was not challenging for over a third of groups.

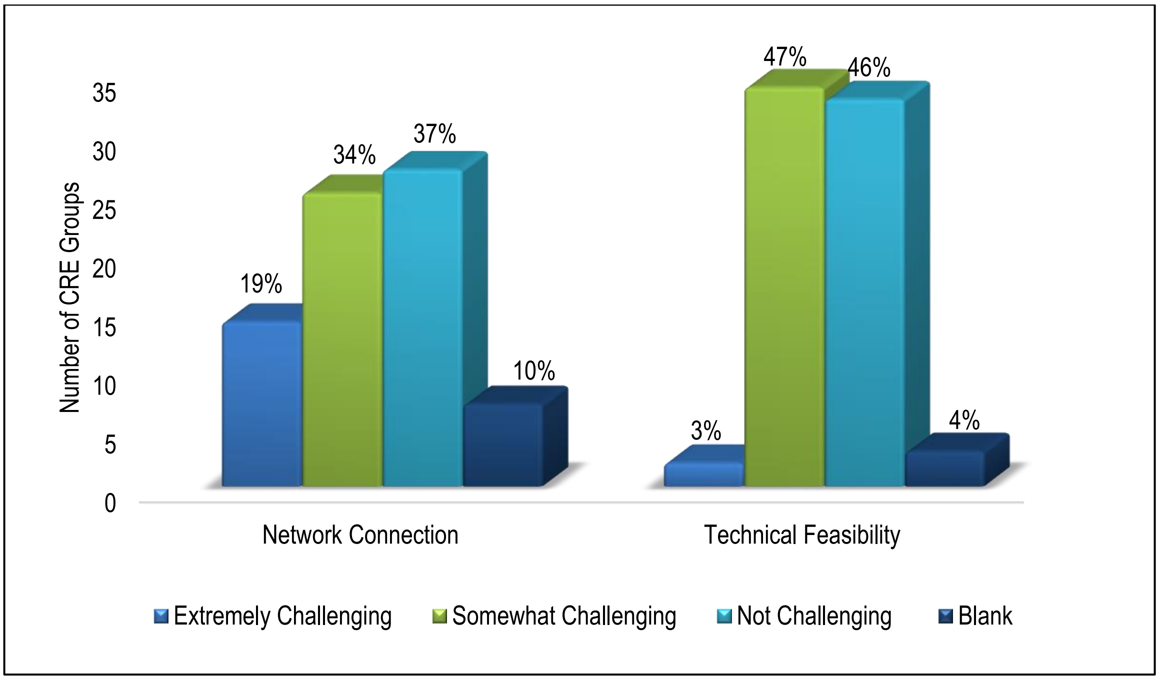

Figure 4.16 The Primary Technical Challenges Facing CRE Projects in the UK

One r*espondent who was involved in a non-active hydro project in Scotland stated that:*

"We paid £42 K to [company] for grid connection in September 2014, to be connected in September 2016. However, a year before our grid connection was due, we were informed

that it would be postponed to 2020 because of network capacity issues. We were given the option of waiting until 2020, or getting connected with only 50 kW rather than 100 kW, as in the initial plans. This would have made raising money difficult and halved our income."

Technical feasibility does not appear to have been at major barrier for the majority of CRE groups; 46% of the groups reported that it wasn't a challenge at all, and only 47% found it somewhat challenging.

However, the semi-structured interviews conducted indicate that community-owned solar projects have faced other technical issues, such as the difficulty in installing export meters in host organisations like schools, and monitoring renewable energy production after installation.

One respondent from a community solar project in London stated that:

"*Obtaining export meters for schools was very challenging and time-consuming because of the third-party ownership model of our projects".*

4.4.5 Lack of Resources

Another barrier which CRE groups encountered in the study was the lack of sufficient resources including skilled volunteers as well as knowledge to deliver and develop CRE projects.

Figure 4.17 illustrates that finding volunteers in the first place was a greater challenge for most CRE projects than the difficulties posed by a lack of sufficient skills and knowledge.

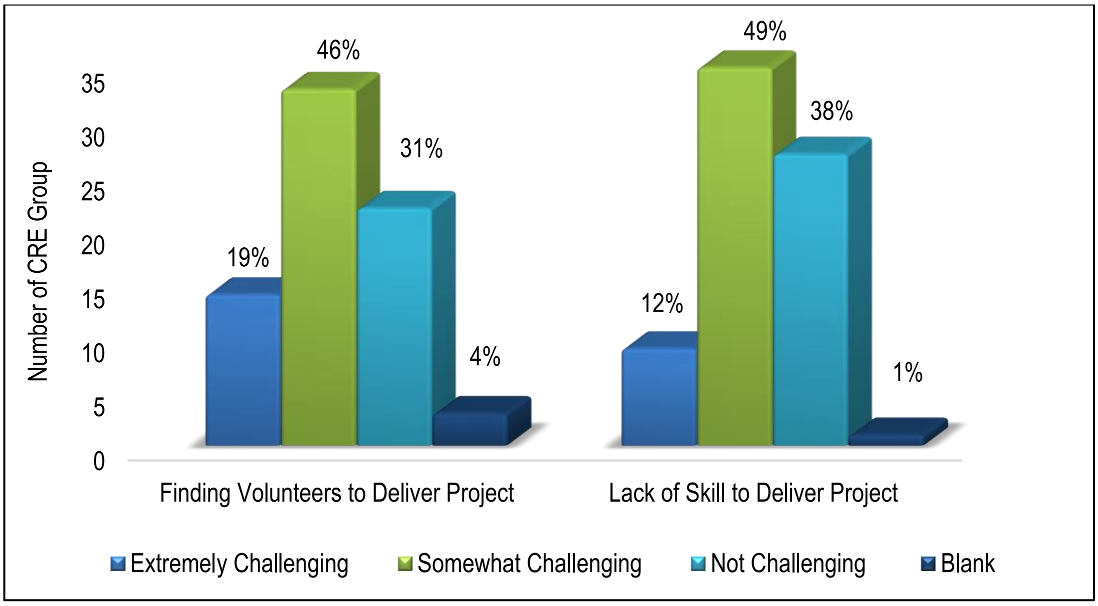

Figure 4.17 Lack of Resources Facing UK CRE Projects Pre- 201

Studies have shown that CRE groups can try to overcome these challenges by integrating their activities with other similar groups and networking with local authorities to access additional staffing and organisational support (DECC, 2013).

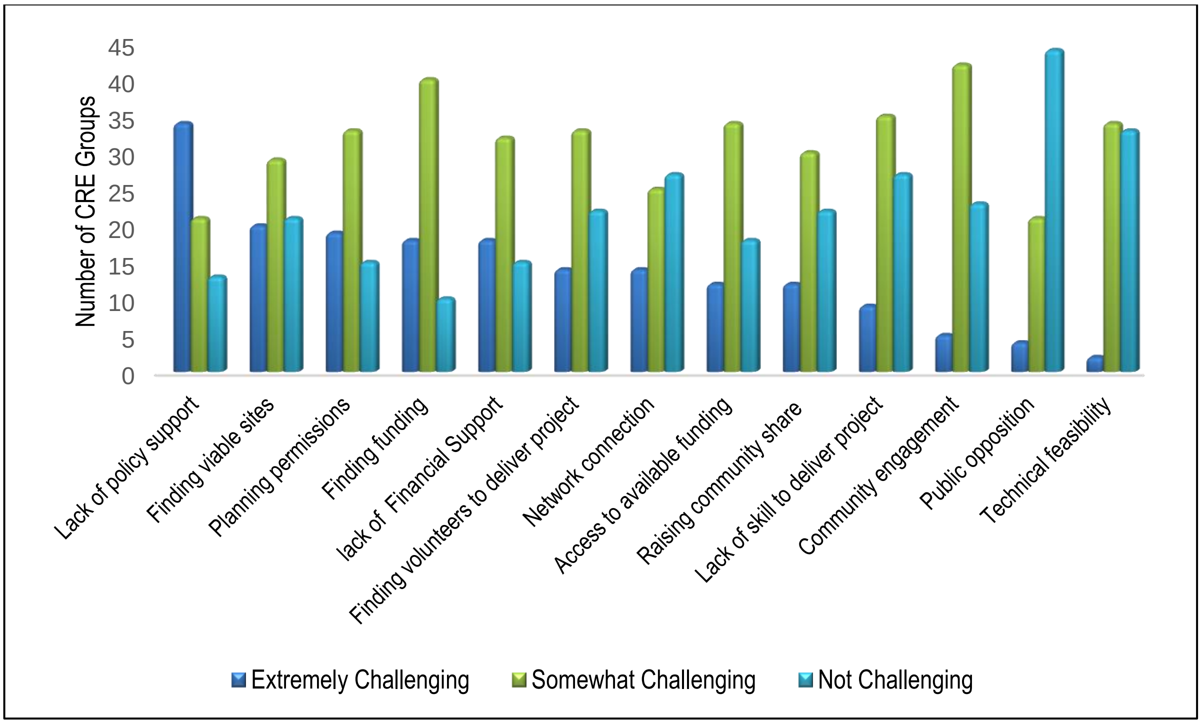

Figure 4.18 The Predominant Challenges Facing CRE Projects during their Development

This study has shown that the main obstacles facing CRE groups in the study during project development (pre-2016) were a lack of structured policy support, the difficulty in finding viable sites, and the lack of financial support and funding opportunities (Figure 4.18)

4.5 Key Success Factors in Fostering of UK's CRE Projects Pre 2016

This section evaluates key factors and Government strategies in the successful development of CRE projects in the UK before RE policy changes (pre 2016). Participants were asked to provide their opinions on the most commonly cited success factors in CRE development, and to comment on the effectiveness of different support schemes.

4.5.1 Funding Sources

This study aims to evaluate the effectiveness of different funding sources that are available to CRE projects in the UK, including Government funding schemes, commercial funding, social and private funding which could provide support from the point of feasibility study to planning application.

This study shows that Government funding schemes have played a significant role in catalysing the development of CRE. As Figure 4.19 indicates 40% of respondents found the Government funding scheme extremely effective, and 25% found it somewhat effective.

In England, the UCEF and the RCEF supported community projects by providing loans during the initial development phase, and further grants during the feasibility phase. The main advantage of these schemes is that they offered 'contingent loans,' meaning that if a CRE group failed to reach the end of its construction phase, it would not have to pay any of the loan back. However, the UCEF was terminated on July 5th 2016. The withdrawal of this source of funds, which was crucial for the development of many CRE projects in urban areas will undoubtedly make it extremely challenging to develop further projects and may even completely stop the growth of this sector in the urban area (Centre for Sustainable Energy, 2016).

In regard UCEF effectiveness a CRE organisation stated that:

“UCEF grants were a key funding source for our projects; we used UCEF three times for project development, twice for our solar projects, and once for a heat project. The fact that it announced its closure in July 2016 made us rush to apply for our renewable heat energy projects, but otherwise we would have done some further research before deciding to complete the UCEF application for renewable heat.”

In Wales, the Ynni’r Fro programme is run across the country and provides support for the development of CRE projects, in the form of grants, loans and practical advice from development experts. Grants of up to £30,000 are available in the early stages of development, including during the feasibility study stage, and loans are also available to help fund the construction of projects (Welsh Government, 2014).

In Scotland, several funding schemes are available which are designed to provide support to CRE schemes. The most important of these was the financial support offered by the Community and Renewable Energy Scheme (CARES). This funding scheme delivers two key sources of finance including feasibility study grants of up to £20,000, and pre-planning loans of up to £150,000 (Haggett et al., 2014). In addition to this, an approved successful CRE project can apply for the Renewable Energy Investment Fund (REIF). The REIF provides flexible capital support to communities which can be adapted for each specific project (Haggett et al., 2014).

This study shows that using funding from the Non-Governmental Organisation (NGO) financial sector is not common among UK CRE groups, with over half of the groups who participated not using these sources of finance. This can be due to the high perceived risk of taking out of a large loan, and the high interest rate (between 7% and 8%). Furthermore, it can be difficult for CRE groups to convince investors that their projects are a profitable opportunity.

A respondent from a community solar project in England stated:

"*We applied to get funding from different sources but we were unsuccessful, and therefore our key funding source was UCEF.*"

The findings from this study mirror the findings of Julian and Olliver (2014) who argued that the challenges of finding an investor for a CRE project can be due to:

i) CRE groups in the UK adopting many different business structures which makes it challenging for investors to determine which models are more likely to provide a reasonable rate of return

ii) A lack of belief in the success of CRE groups that discourages potential investors and deters them from learning about their business structures. Together these can significantly limit CRE organisations' access to retail funding and key SME resources, preventing potential investment, and money lending.

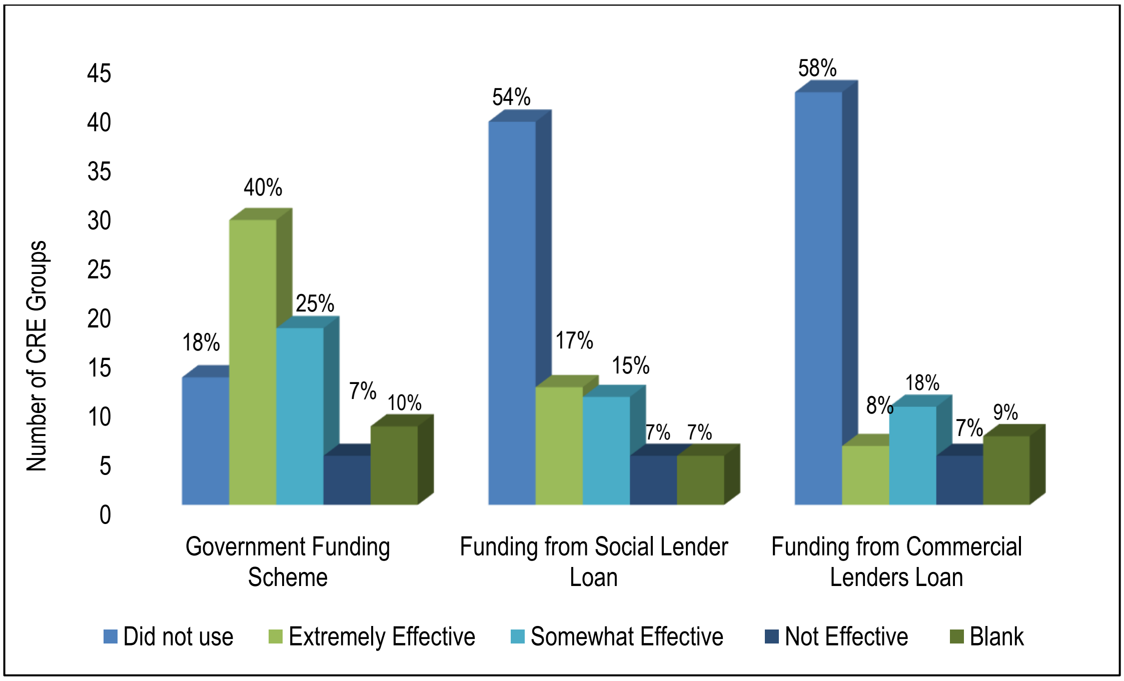

Figure 4.19 The Effectiveness of Available Funding Schemes

However, among the respondents who did use funding from social lenders, 17% found it extremely effective and 15% found it somewhat effective (Figure 4.19). Borrowing from commercial lenders was a less popular option amongst CRE organisations, with only 33% of the group using it. Only 8% of respondents found money from commercial lenders to be extremely effective, followed by 18% who found it somewhat effective. The Energy Prospects Co-op is an example of an emerging commercial funder which supports CRE development in the UK and has been used by groups in the study. It aims to fund the early stages of a project's development. This can come into effect once a project has gained planning permission, and the co-op project can raise finance to pay Energy Prospects Co-op fees (Energy Prospects Co- operative, 2018).

4.5.2 Incentive Scheme

The aim of this section is to evaluate the effectiveness of the different Incentive schemes which were in place between 2010 and 2016 to support and promote investment in renewable energy and energy efficiency, from the perspective of a CRE group representative.

As Figure 4.20 shows, the majority of groups which took part in the study (61%) found the FIT an extremely effective policy mechanism for supporting their development. However, the rates of the FIT were dramatically reduced in 2016.

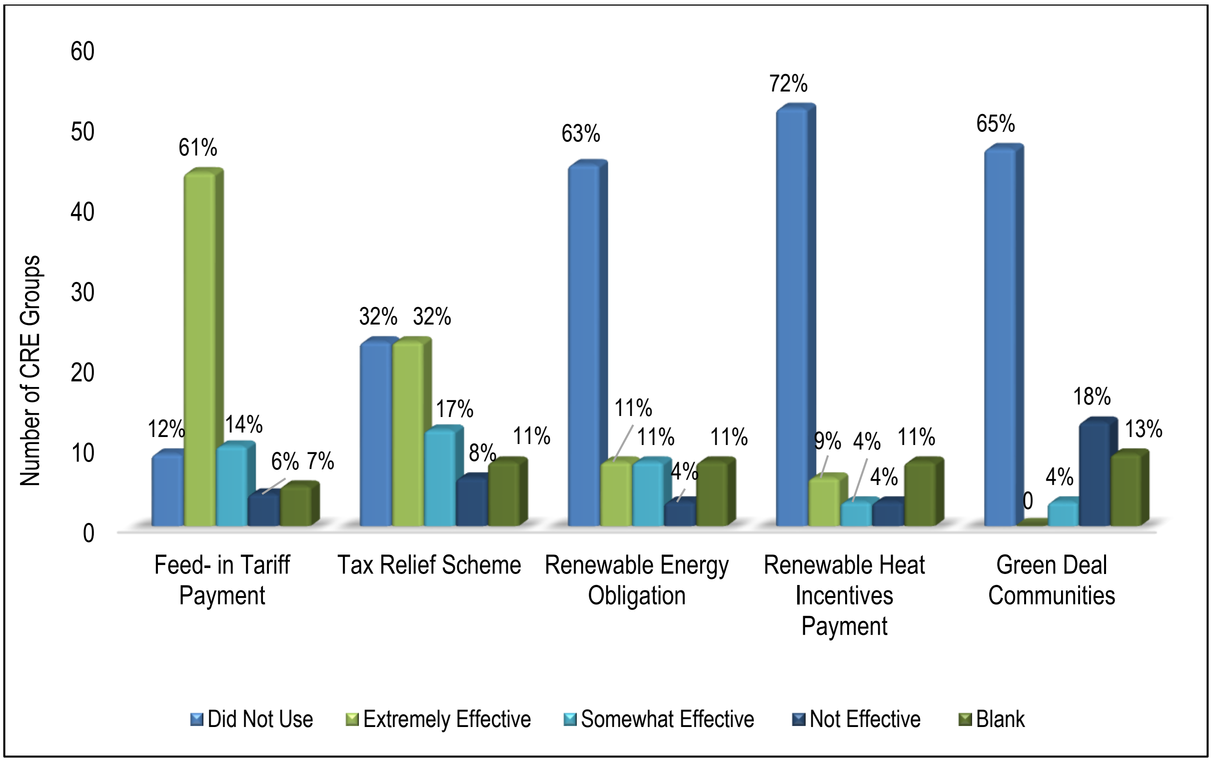

Figure 4.20 The Impact of Recent Incentives (2010-2016) on the Success of CRE Groups

The UK Government has delivered two different Tax Relief schemes to try to help overcome the challenges facing CRE group by reducing the high risk involved in investment (See CHAPTER 2 section 2.5.2). However, the only projects that were eligible for these schemes had to be established between 2012 and November 2015.

32% of the groups who made use of these schemes reported that these Tax Relief schemes were extremely effective in overcoming the challenges posed by the high-risk investment in CRE groups, followed by 17% of groups who found the policies somewhat effective (Figure 4.20).

As the RHI only covers renewable heat projects, a large number of groups in this study which focused purely on electricity generation did not make use of the scheme. Although following the reduction in FIT rates, community heat projects are also emerging.

Renewable Obligation (RO) provides support for the large-scale generation of renewable electricity, so only a small proportion of groups in the study were able to make use of this incentive. Amongst those that did, 11% found it to be extremely effective, followed by 11% who found it somewhat effective. This support was phased out in 2015 and replaced by the comparative market-based approach called Contract for Difference (CFD).

The Green Deal initiative was not popular amongst local energy saving groups, and many did not use it despite running energy efficiency projects. 18% of those that used the initiative did not find it helpful, and as a consequence, it was phased out in July 2015 without any replacement.

This study indicates that among the recent policy support schemes (between 2010 and 2016) which were designed to promote investment in renewable energy and energy efficiency, the FIT and Tax Relief schemes had a significant positive influence on the development of CRE projects in the UK, as they increased their financial viability. However, with many of the renewable support mechanisms ending, it became considerably more challenging for CRE organisations to develop further projects, and virtually impossible for any new groups to establish themselves within the sector.

4.5.3 Local and Regional Support and Partnership

This study emphasises the importance of partnership between organisations, both regionally and locally, and CRE projects in the development of this sector. The results show that the majority of CRE groups which took part in the study have received support from other organisations for developing their projects, rather than acting completely on their own.

The UK's local authorities and councils have been actively supporting CRE groups in recent years and have played an effective role in their success. Nearly a third of respondents found support from local authorities and local councils to be extremely effective, and 29% found their support somewhat effective (Figure 4.21).

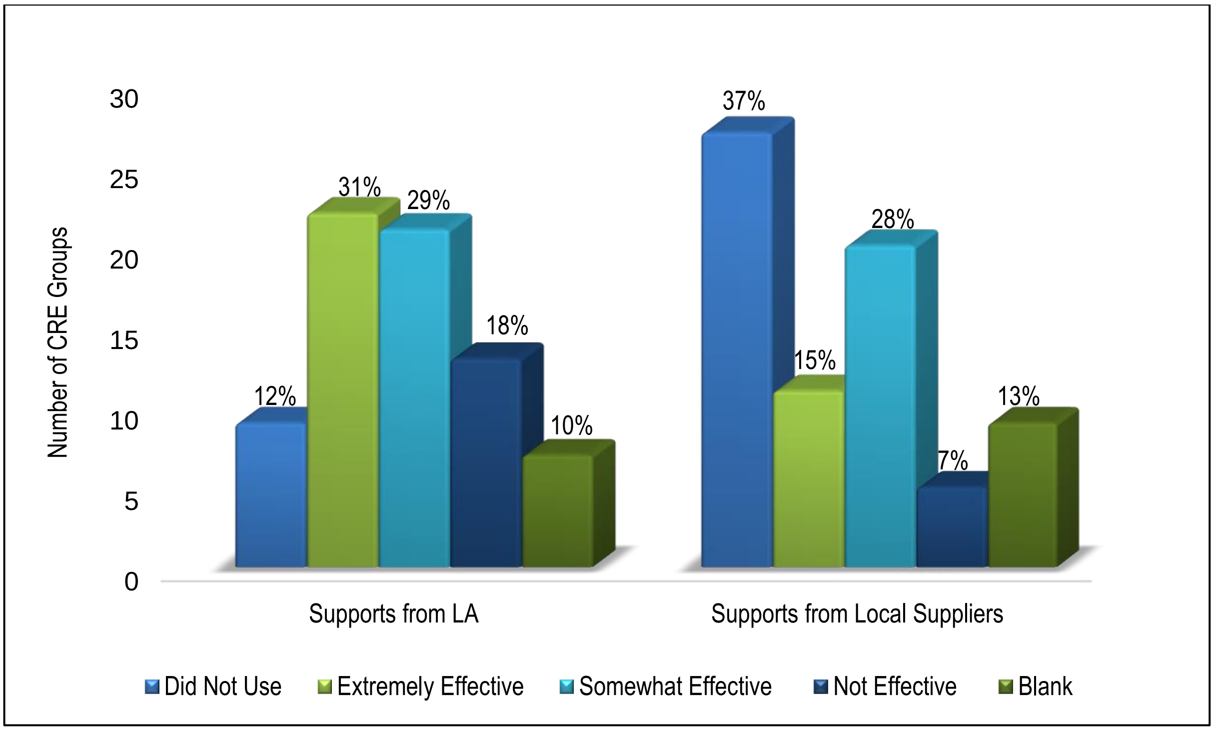

Figure 4.21 The Role of Local and Regional Partnership on the Success of CRE Groups

Our study found that local authorities and councils have supported CRE projects in diverse ways, including providing staff and organisational support to CRE organisations. For example, Brixton Community Solar, located in London stated that, they have received staffing support from Lambeth local council, which overcame the challenge of sourcing sufficient volunteers to deliver projects efficiently.

Several groups in the study reported that the local authorities and councils had supported their projects by informing and teaching them about funding applications and the technical and institutional processes involved in the early stages of setting up a project.

Some groups stated that their local authorities played an important role in promoting their projects within the wider community, and a small number of groups specified that their local council provided the opportunity for them to install solar PV on the buildings that they owned.

Local suppliers can support CRE groups by offering community benefits funds, which support local energy efficiency, renewable energy initiatives, and by buying the electricity generated by CRE projects at a reasonable and agreed price. This should enable CRE projects to benefit more from their local renewable generation. However, this study has revealed that receiving support from an energy supplier is not common in the UK, or in other words, they are not as active as local authorities and councils in supporting local energy activity. Over a third of the CRE groups which took part in the study did not receive any support from their local supplier. While 28% of groups who used support from a local energy supplier found it to be somewhat effective, only 15% who found it to be extremely effective (Figure 4.21).

In addition to local and regional support, other organisations such as universities, existing local cooperatives, and other community projects have supported CRE groups in their project development in various ways, for example, by providing technical support, by promoting the groups within the wider community, and by providing the groups with a location to meet and discuss projects for no charge.

One respondent from a CRE group located in England stated that:

"Finding sites was the main barrier to the development of our projects. We managed to overcome this barrier with the help of our partner, [x] Co-operative Development Agency, who introduced us to two of the schools we now use, which was a massive help for the development of our projects."

4.5.4 Networking and Available Information

In recent years several active local and regional network organisations (such as Community Energy England and Community Energy Scotland, Bristol Energy Network) have emerged, which supported the development CRE projects. These organisations provide networking around knowledge and experience exchange for CRE groups, organising workshops and conferences as well as lobbying activities behalf of CRE groups.

The importance of membership in local and regional network organisations has been highlighted by 39% of groups in the study who reported this as a key success factor for their project development followed by nearly a third who it found somewhat effective.

Although 19% of the group in the study was not a member of any local or regional organisation (Figure 4.22).There are also several intermediary organisations which provide information and advice to CRE projects during different stages of their development and operation, including 10:10 Climate Action, the Centre for Sustainable Energy, Co-operative UK and the Energy Saving Trust.

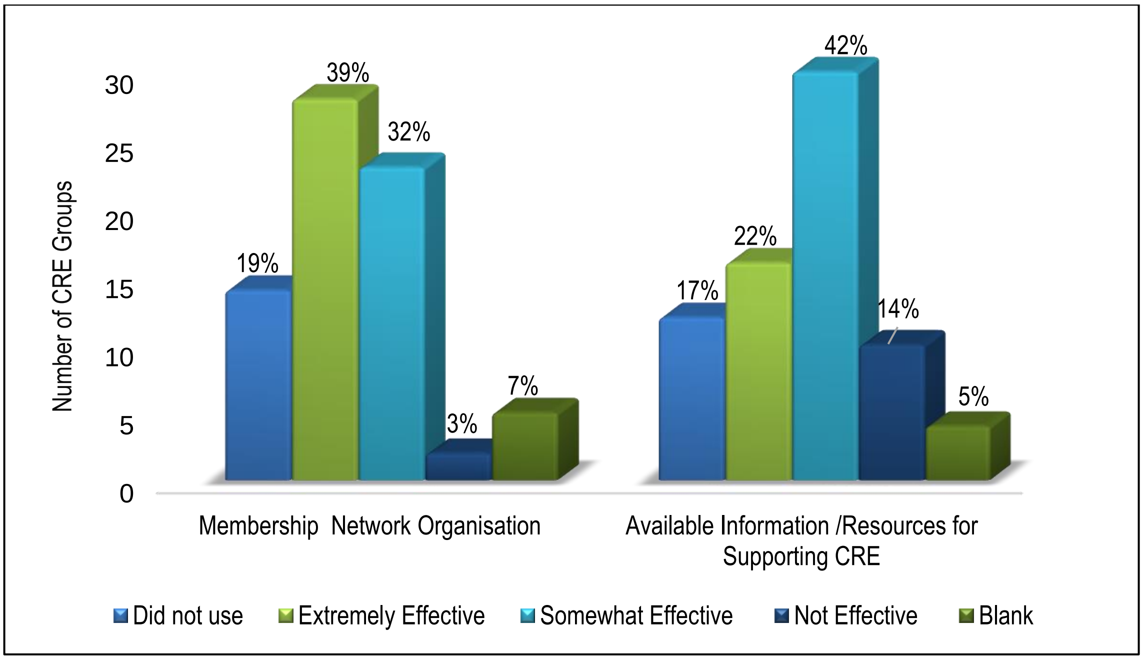

Figure 4.22 The Impact of Networking on CRE Development

The aim was to evaluate the impact of available advice and information on the success of the UK's CRE projects: 22% of the groups reported that available information and advice played an extremely effective role in the success of their projects, and 42% reported that it was somewhat effective (Figure 4.22).

The findings of Seyfang et al. (2014) suggest that the UK CRE sector is in its 'inter-local' phase meaning that an emerging niche is manifest, but it is incoherent in terms of direction, and neither robust nor influential.

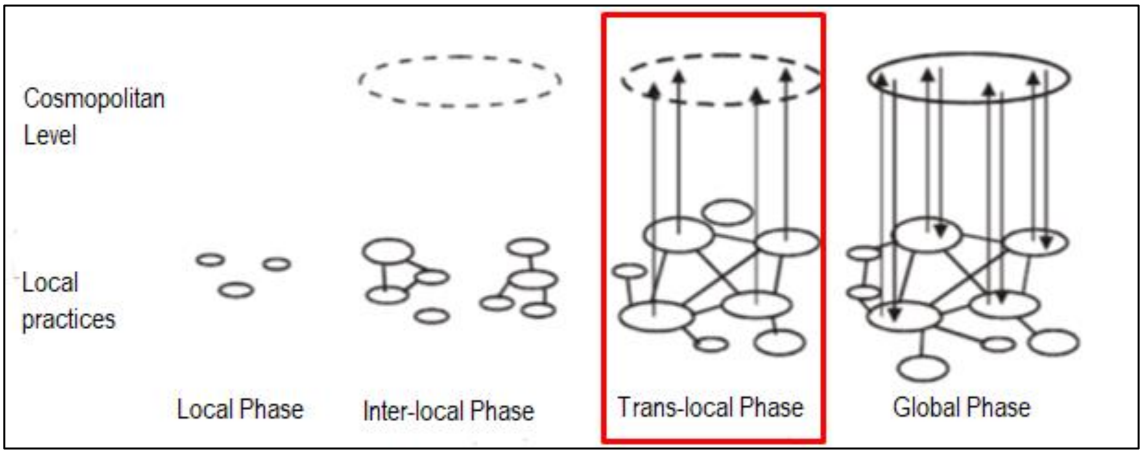

Figure 4.23 Phases in Shared of Technological Knowledge ;(Geels and Deuten, 2006)

Seyfang et al. (2014) argue that UK Community energy projects tend to exchange knowledge between each other rather than through dedicated networking and intermediary organisations. However, findings of this study show that in the recent years there was an improvement and the UK's CRE projects are steadily entering the 'trans-local' phase. As more intermediary and network organisations emerge, meaning that knowledge exchange will begin to take place within widespread circulations (Figure 4.23).

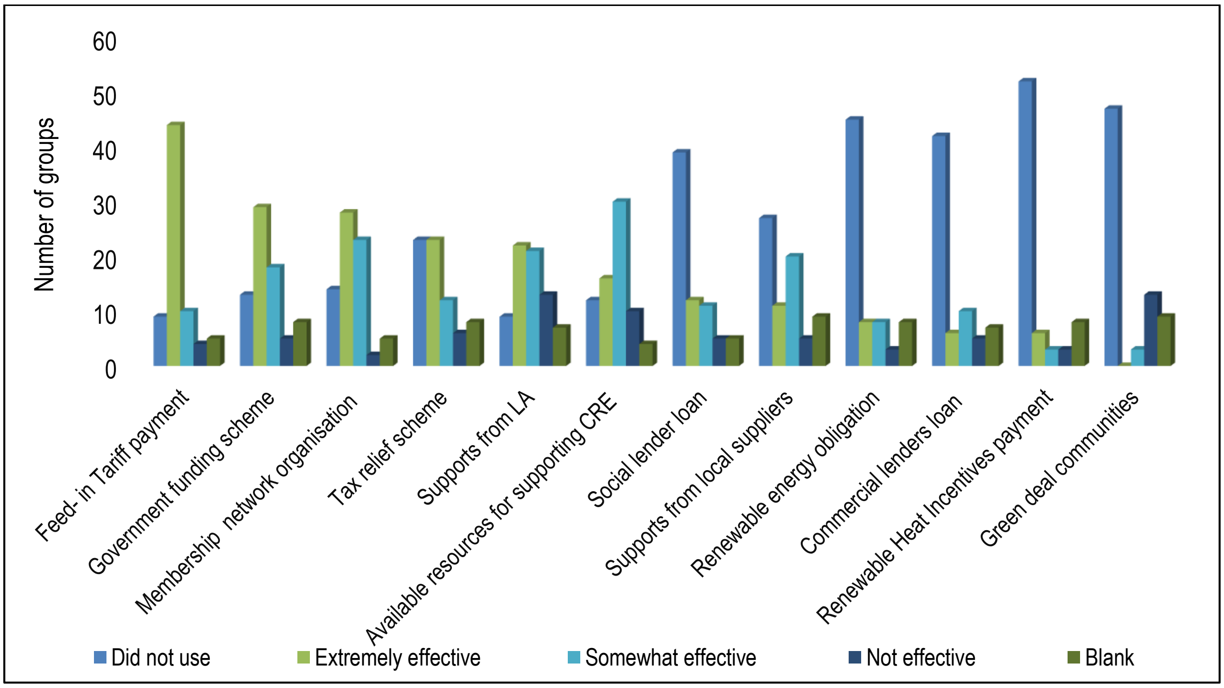

Figure 4.24 Key Success Factors of Development of CRE Group

This study illustrates that the key success factors for the UK's existing CRE projects are the

FIT scheme, Government funding schemes, and memberships with networking organisations (Figure 4.24).

The results from the semi-structured interviews indicate that in addition to all external enablers, the local culture of an area which hosts a CRE project, also plays an important role in the success of CRE projects.

For example, one participant from London stated that:

"*We were quite fortunate that our organisation is located in a place where there are many environmental activists within the community."*

It was also highlighted by two groups which were interviewed that internal factors such as the skills of those involved in the organisations, have played a large role in the success of their projects.

"For our first share offer (4 solar school projects) the feasibility studies were carried out by our previous voluntary director, who was an engineer and worked for the solar company, which helped us massively and reduced the cost of our projects."

Furthermore, the CEO of a CRE group located in England stated that:

"Raising community share and public engagement for our projects was not challenging because my background is in community engagement."

4.6 Evaluating the Consistency between the Findings from the Part 1 Survey and the Semi-structured Interviews

The aim of conducting semi-structured interviews was to validate the collected data from the questionnaire. The interview results have confirmed the reliability of the survey results and provided a qualitative understanding of the CRE project business model, the challenges facing these projects, and the factors which were influential in their success. Furthermore, conducting interviews enabled this study to generate an empirical understanding of the CRE sector and explore areas that the survey did not cover.

4.7 Conclusion

This chapter has provided robust evidence of the recent activities of CRE groups and mapped different elements of the UK's CRE business model structure, and therefore enabling the assessment of potential alternative business models.

It has shown that the UK's CRE projects can be split into three different types of business models. These include the community-financed business model, the community partnership model and the non-energy focused organisation. Among these models the community financed business model was the most commonly used by the CRE groups within the study.

The UK's community energy sector has seen significant growth in recent years (between 2011 and 2016), particularly in its number of solar projects. Our surveys provide robust evidence of the recent activities and challenges faced by the CRE sector during project development. Although the sector has been supported by the Government via different public subsidies and grants, this support has clearly not been consistent. Inconsistency and contradiction in CRE policy support are the key reasons for the slow progress of projects in the UK. The lack of structured policy support for CRE projects, as well as the difficulty in identifying viable sites were the greatest challenges faced by the UK's CRE sector during the project development stage.

Nevertheless, this study has shown that recent policy measures such as the Community Energy Strategy and financial incentive schemes (FIT, UCEF and RCEF) have helped to overcome these challenges to some extent and foster the development of CRE projects. The majority of CRE groups that took part in the study stated that the FIT scheme was the most important success factor for their existing projects. Therefore, since January 2016 when the reduction of FIT was announced, community-based projects have faced huge financial challenges. The following chapter evaluates the impact of the renewable energy (support mechanisms) curtailment that occurred in 2015, on the development of the UK's CRE sector.

CHAPTER 5 KEY FINDINGS PART II: THE IMPACT OF RE POLICY CHANGES

5.1 Introduction

This chapter presents the second part of the results of our survey and the semi-structured interviews carried out. This chapter investigate the impact of the curtailment of renewable support mechanisms on the development of the UK's CRE sector. This chapter goes further to evaluate barriers facing CRE organisations looking to develop under new policy conditions. If the UK Government wants CRE organisations to play a significant role in the country's energy transition in the future, it is critical to recognise potential barriers that could limit their development now.

The first section of this chapter discusses the challenges faced by CRE projects under new policy conditions, following by an evaluation of the different business models that CRE groups can potentially adopt under the new policy conditions.

5.2 The Impact of Post-2015 Policy Changes on Community Energy Activities

According to Hielscher et al., (2010), the UK's community energy is an emerging and niche sector which is significantly vulnerable and sensitive to policy change, meaning that uncertainty surrounding the amount of support that the Government can provide can be detrimental for community-led groups. As Figure 5.1 indicates, 69% of groups in the study reported that the FIT reduction had adversely affected their projects' development, and 15% confirmed that their projects were affected by the removal of the FIT pre-accreditation.

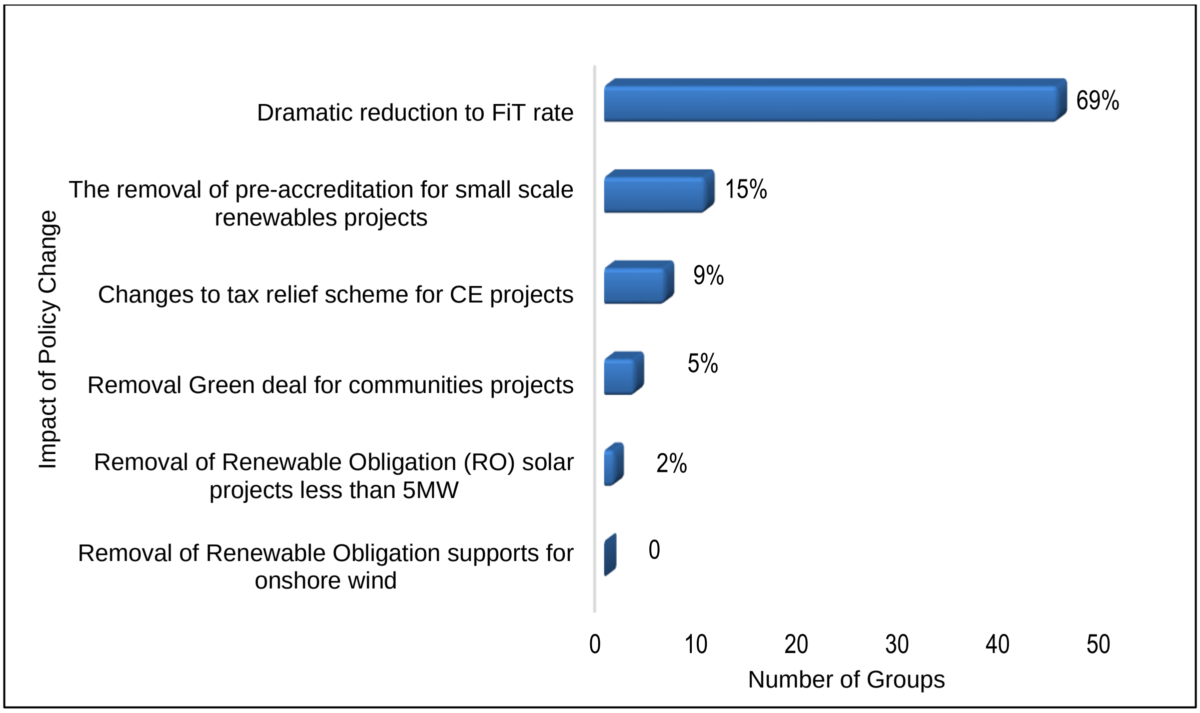

Figure 5.1 The Impact of Policy Changes on CRE Projects

FIT pre-accreditation was introduced alongside the FIT reduction in 2012, and it ended on 8th February 2016 for community groups (Nolden, 2015). With FIT pre-accreditation, RE projects which generated over 50 kW of energy, and which had planning consent and grid connection, were able to receive a guaranteed FIT level before the projects start (Ofgem, 2016a). Community groups which produced less than 50 kW of energy through solar PV could access pre-registration. With FIT pre-accreditation and pre-registration, organisations have certainty about the price that will be charged for the electricity that they produce. Removing FIT pre-accreditation and pre-registration meant that any projects that were subsequently planned would only be entitled to receive the rate of subsidy at the date that their projects were completed.

5.2.1 Reasons Why Some CRE Projects Failed, Following Policy Changes

Community energy projects are not widely diffused in the UK, and are therefore very vulnerable to changes in Government (Nolden, 2013b; Seyfang et al., 2013). Recent policy uncertainty has made it challenging for projects to be successful, and virtually impossible for any new groups entering the sector. Notably, our survey findings supported the statement of (Seyfang and Haxeltine, 2010), which emphasises the fact that community-led ‘grassroots’ innovation tends to remain relatively small-scale and fails to develop without institutional and long-term financial support (Hielscher et al., 2010).

The majority (68%) of CRE organisations in the study had more than one scheme (between 1 to 3 sites), overall groups in the study had 502 RE schemes[2]. CRE groups in the study reported that in total 89 of their schemes/sites either in planning or feasibility stage did not go ahead, 10% of these organisations were at the stage of developing their first RE projects, but failed due to policy uncertainty and have since become inactive. Some community organisations expressed the following reasons for discontinuing their business:

A hydro scheme located in the South of England and established in 2010, reported that:

“We had pre-accreditation, but that set a time limit which made construction more expensive. Our project got as far as tenders, but the price turned out to be much higher than the QS estimate so the project was not viable. Shares have now been bought back and the Society is being dissolved”.

A small-scale hydro scheme established in 2009 in England stated:

“*Our small-scale hydro scheme on the river [xxxx] had reached the stage of submitting a planning application, but was rendered no longer viable by the reduction in FIT rate and changes to the Tax Relief scheme*.”

[2] It should be noted that one of the organisations in the study had 314 RE schemes/sites.

Another in-active scheme located in Wales stated that:

"*Our grant funding was cancelled in advance research feasibility phase due to FIT reduction although our project was feasible."*

These statements indicate that small-scale hydro schemes newly set up prior to the FIT reduction and pre-accreditation removal were unsuccessful in completing their project installations due to time limits and cost. The FIT generation payment for hydro schemes generating less than 500kW energy was reduced dramatically with periodic degression, causing widespread financial unviability for hydro schemes. The British Hydropower Association (BHA) supports this conclusion, with their figures showing that many new applications for water extraction failed during the years of 2014 and 2015 due to FIT degression over time. Furthermore, the voluntary nature of community energy organisations cannot compete in this uncertain institutional landscape due to their lack of resources (paid staff).

A respondent located in Wales stated:

"*Although our 30 kW Anaerobic Digestion and 30 kW solar project were at feasibility stage the removal of Government support made it much harder for a small group of enthusiastic local members to continue with the project."*

The main reason for CRE project failure in South West England, according to an organisation in Cornwall who had three volunteers and no paid employee, is:

"*Due to a lack of people in our group, we weren't able to develop the project fast enough before subsidies went."*

Out of 89 schemes that did not go ahead, 20 provided installed capacity details for their potential projects. The 20 schemes which did not go ahead accounted for approximately 18MW electricity, including 14MW of solar PV energy across seven schemes, 400 kW hydro energy across four schemes, 3.5MW onshore wind energy across seven schemes and 350 kW AD energy across two schemes.

This study shows that the FIT reduction and removal of FIT pre-registration were significantly disruptive to community solar projects, with respondents stating that they failed to complete 71 of their community-led solar schemes (Table 5.1). The most common reasons reported included the economic unviability of their projects due to the reduction of FIT, missing FIT deadlines due to a lack of resources (volunteer), and refused planning permission for large-scale projects.

Table 5.1 Projects which Failed Due to Post-2015 Policy Changes

Name of Technology	Number Scheme	Cause of Projects Failure (based on survey respondents)
Hydro	8	- High risk with the lack of pre-accreditation - Missed FIT pre-accreditation deadlines -Grid connection constraint refused -Time limit caused construction to be more expensive
Solar	71	- Missed FIT pre-accreditation deadline - Lead partner refused to become an energy supplier, "largely on the basis of the post-election ministerial statement" - Made it unviable by FIT reduction - Lack of resources – enough people to deliver the project
Wind	8	- Planning permission refused due to ministerial statement of June 2015
Anaerobic Digestion	2	- Substantial risk involved
Grand Total	89	-----

The main reason reported for the failure of hydro projects was the high risk posed by instability following the removal of FIT pre-accreditation, the refusal of grid connection for 100 kW hydro schemes, and missing the deadline of FIT pre-accreditation. The removal of pre-accreditation increased the investment risk to community energy projects, in particular hydro schemes which typically took between 2 to 5 years to be fully developed.

5.3 Challenges Facing CRE Organisations Business Model under New Renewable Policy Conditions

Several internal and external barriers facing CRE groups have been identified which inhibit the development of new project after policy changes. These challenges are found within some elements of the business model Canvas outlined in Table 5.2.

Table 5.2 The Main Challenges to CRE Projects under New Policy Conditions Based on (Osterwalder, 2004; Osterwalder, 2005)

Elements of the business model Canvas	Internal barriers	Percentage	External barriers	Percentage
Key resources	**Lack of knowledge to develop business model for new projects (business model innovation)**	23%	-----------------	-----------------
Financial model (upfront cost)	Difficulty in raising capital through community share due to the lack of profitability	15%	- Finding funding due to the policy changes (such as withdrawal of the UCEF)	16%
Revenue	**Lack of viable business model and substantial risk**	15%	- Lack of structured policy supports	18%
Other factors	Community engagement	5%	---------------------	
	Locating viable sites for new projects	8%	---------------------	

This study reveals that the lack of sufficient knowledge in the communities to develop and identify new business models for projects is a key challenge facing 23% of community-based energy groups in post-subsidy conditions.

The second key barrier identified by 18% of respondents was a lack of structured policy support which is categorised in Table 5.2 as an external barrier to CRE business model structure. The lack of policy support was often the greatest challenge facing the development of CRE groups, even before the curtailment of support mechanisms was implemented (Nolden, 2013a). The assurance provided by FIT did not determine whether their planned project would go ahead or not (Nolden, 2013a).

Under the new policy conditions 15% of respondents reported that, raising capital from members of the community would be more challenging with a smaller return on investment and an unknown rate of FIT. Previously the FIT scheme delivered a return between 5% and 8% on the investment of small-scale RE. With the new reduced FIT, however return on investment decreased to around 1%, and therefore it is not a particularly attractive incentive for members of communities:

"*We had originally planned to install roof-top solar PV on 20 sites, but 16 did not go ahead because of the removal of pre-registration and reduction in FIT. Both had a serious impact, but the pre-registration was arguably worse because it meant we had no way of knowing what the FIT rate would be when the sites were accredited, and this uncertainty would make it incredibly difficult to raise the required capital from members of the community*."

Public subsidies, in particular FIT, have been central to community energy projects in the UK and dramatic changes to the policy landscape have made them financially unviable, 15% of respondents reported that lack of a viable business model and substantial risk after, removal of FIT accreditation was the main barrier faced by their projects.

Another challenge stressed by several groups in the study, in particular to those financing distributed solar PV, was locating viable sites for generating energy, because there is very little financial incentive for site-owners now that FIT has been reduced.

One respondent stated that:

“*Economic viability is much harder with reduced FIT. PPA now needs to charge almost as much as grid, so financial incentives for site-owners are greatly reduced and it is even harder to obtain a roof-top lease and a PPA agreement. You also need to have a high proportion of on-site use for viability. The loss of pre-accreditation causes forward-planning to be packed with uncertainty and risk. Tax Relief removal was unhelpful, but not the main problem.*”

5.4 UK’s CRE Organisations Approaches under The New Policy Conditions

Figure 5.2 indicates strategic approaches that CRE groups in this study have undertaken or are planning to undertake, some of which can already be observed in the market.

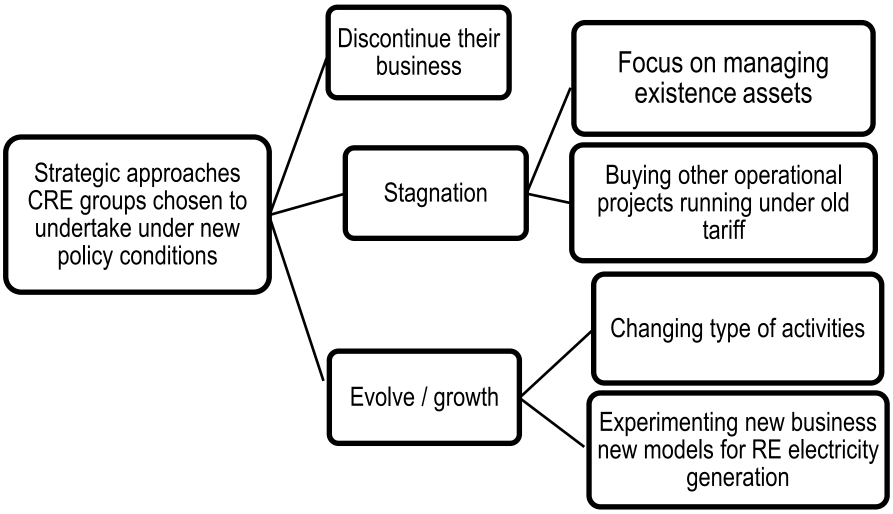

Figure 5.2 Strategic Approach Undertaken by UK CRE Groups under New Policy Regime

10% of CRE groups who took part in the study forced to discontinue their businesses due to policy change. 51% of survey respondents chose to focus on managing their existing assets, rather than developing further projects (stagnation). It has been argued that grassroots projects spend most of their time simply trying to maintain their level of survival, and only a small amount of time developing (Seyfang and Smith, 2007).

The majority of groups who chose to focus on managing their existing projects reported that their members lost the motivation to develop further projects within the sector as a result of institutional changes.

One community representative specified that:

“It is harder to raise community share capital for community energy schemes, and therefore we have stopped looking for new projects.”

A respondent located in England stated:

“*The changes removed our motivation to begin further projects.*”

Only 39% of respondents were planning on undertaking new projects under the new RE policy conditions.

5.4.1 Future Activities of Community Energy Projects under the New Policy Condations

Among groups who were hoping to undertake new projects, the majority of groups reported that they would change their key activity i.e. evolve.

As Figure 5.3 shows, 28% reported that their new projects will primarily focus on energy efficiency projects, 21% mentioned that they are planning to identify and experiment with a new business model (such as microgeneration with storage), and 15% reported that they will focus on renewable heat projects. Some groups stated that their projects will involve investment on LED lighting (energy efficiency) in the future, which would enable community buildings to reduce their energy cost and emissions. Some stated that they were planning to take on projects under the new FIT rate (12% for PV and 6% for wind).

However, 15% of groups who were hoping to undertake new projects reported that they plan to buy other operational RE projects running under an old FIT rate (Figure 5.3).

This approach will not add to RE capacity in the energy system, but instead will only help community groups survive and continue operating, and therefore it is considered to be a form of stagnation.

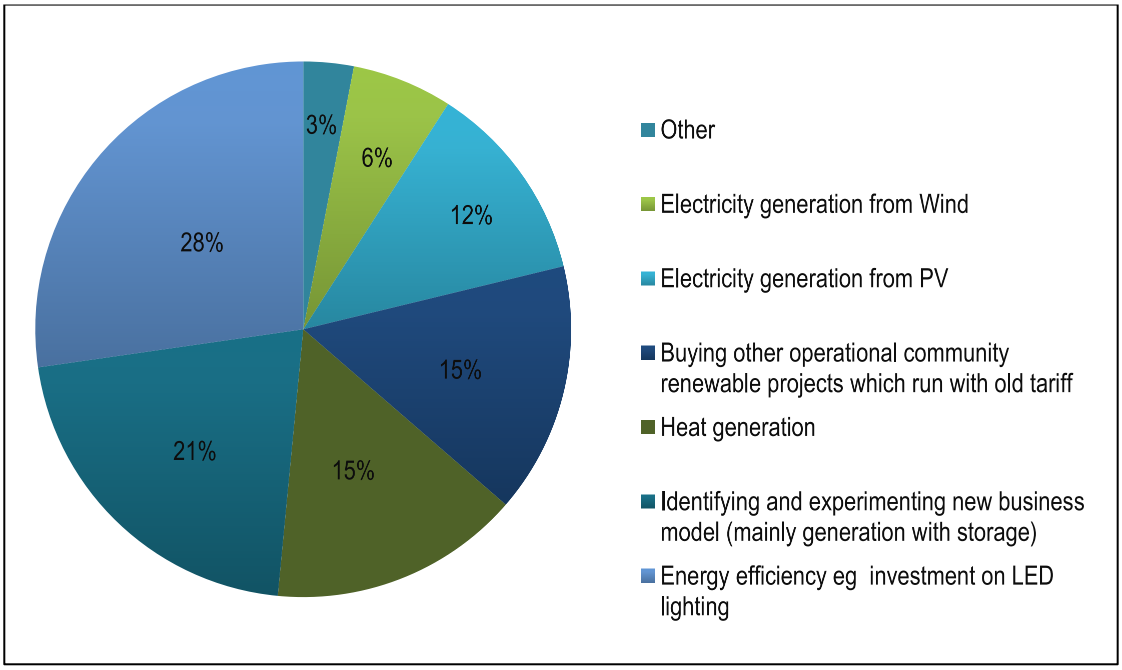

Figure 5.3 What type of activities will occur under the new policy regime? (n=28)

5.4.2 Business Model Innovation for The UK's CRE Projects under New Policy Conditions

We have discussed the strategies that CRE organisations are undertaking to overcome certain barriers introduced by reduction in the FIT generation rate. Now we will provide a brief overview of the challenges facing CRE organisations looking to develop an innovative business model for further growth and maintain an existing level of productivity, given the current regulation in the UK.

Business models can be crucial catalysts for the diffusion of new technologies in tackling both internal and external barriers, including reducing uncertainty and dealing with cost reductions (Strupeit and Palm, 2015). According to Bolton & Hannon (2016), business model innovation can involve implementing new business activities, connecting activities in novel ways or changing the way that a certain party carries out an activity. Schneider & Spieth (2013) defined ‘business model innovation’ as fundamental modification to the way firms create and capture value, producing results which will exceed those created by incremental adjustment to an existing business model. Innovative technologies can act as a driver for business model innovation, but some models, such as car-sharing, do not necessarily require technological innovation (Bidmon and Knab, 2014).

Literature on this topic has identified several internal and external barriers obstructing business model innovation. These have been categorised into two sections: those directly related to the business model elements, including a lack of resources (such as time, capital costs, expertise) (Hall and Roelich, 2016; Herbes, et al., 2017; Richter, 2013), and a lack of profitability (Herbes, et al., 2017); and those which are unrelated to elements of the business model and can be caused by other aspects such as a lack of policy support, a lack of public awareness and social acceptance (Aslani and Mohaghar, 2013).

5.4.3 Opportunities and Challenges

Participants of our study were asked to provide their opinions on potential approaches towards innovation that CRE projects could take in the future, under the new renewable policy conditions. As outlined in Table 5.3, 28% of respondents suggested that direct supply business models, which enable organisations to sell electricity directly to local communities or third-parties, might enable conventional community energy schemes to remain viable under the new RE policy regime. For the majority of the UK’s CRE projects and localised energy generation, the only current way of entering the market is through the PPA with a third-party licensed supplier (TPLS) or market trader (Hall and Roelich, 2016).

The terms of the PPA have decreased in recent years and therefore, it is highly likely that localised generators will receive a lower price than the reference price for the power they generate. As a result, this approach is not economically viable under current UK legislation (Hall and Roelich, 2015).

A direct supply model has proved to be successful in other European countries including Germany, but currently in the UK this model is extremely complex and economically unviable (Simpson, 2013). The UK's localised RE schemes should be enabled to effectively and efficiently sell their electricity directly to local customers. The UK Government should facilitate grid access and reduce connection charges for community-owned RE. By taking this approach, CRE projects can remain viable under the new RE policy regime and avoid the 'cliff edge' phenomenon in this sector.

One of the current forms of direct supply is the 'pool and sleeve' model, which aims to aggregate localised energy production (pooling) and supply it to a specific end user without involving further wholesale market intermediaries (sleeving) (Hall and Roelich, 2016). In 2009, the UK Government introduced 'Licence Lite' to enable this model, but unfortunately due to complex licence and cost conditions imposed by the Greater London Authority (GLA) which is still under development, no organisation has yet been granted 'Licence Lite'. However, it is clear that the this model will provide an easy and reliable route for CRE projects in the future, and if simplified, can be extended to all localities (Hall and Roelich, 2016; Simpson, 2013).

Table 5.3 Community Representative Opinion on Potential Approaches for Future Projects

Business Model Class	Business Model	% Suggested By Community Representatives	Replicable For	Potential Barriers
Partnership with supplier	Direct Supply	28%	Conventional CRE projects	-Lack of profitability -Lack of clear public support
	Long term PPA	17%	Conventional CRE projects	-Identifying viable sites -Lack of of viability of existing business model
	Energy Service Companies (ESCo)	11%	Local Authorities and potentially suitable for large CRE groups	-Not suitable for all CRE projects -Very complex to coordinate -Lack of resources -High capital investment -Requires a licence or private network to supply electricity
	Local Aggregation	12%	Large CRE groups, local authorities and potentially small CRE groups	-Require smart meter and half hourly settlement -Bureaucracy complexity
Self-Supply	Private arrangement	12%	Conventional CRE	-Can be challenging to find the right customer -High capital investment -Requires guarantee that demand will remain over lifetime of generation plant
	Generation with storage	20%	Some Conventional CRE	-Lack of resource -**High capital investment** -Lack of public awareness -Difficulty in raising capital -**Lack of established business model**

The next most commonly suggested option was that of RE generation alongside battery storage, proposed by 20% of respondents. Storage can provide many new utilisations opportunities for RE resources, as well as increasing grid reliability and customer flexibility. Furthermore, different revenue streams are available for battery storage including grid flexibility services and demand-side services. However, there is still no established business model for CRE projects to create revenues from providing these services (Table 5.3).

This study shows that some of CRE groups are planning to develop battery storage projects. There are however, a many financial barriers involved in developing projects with this type of model as they will require large capital investment due to the high cost of batteries. Also, these types of projects require more technical and business expertise than conventional CRE projects which were originally based on a low-risk FIT model. Consequently, one of the main internal barriers to CRE organisations for developing these type projects, which are mainly run by volunteers, is the lack of resources including time, knowledge of developing an alternative business model, and the capital costs to run new projects. Further to this, since public awareness surrounding the advantages of battery storage and other decentralised technologies is still limited, raising capital through community share might be challenging.

As Table 5.3 shows 17% of respondents suggested that a long-term PPA may provide the best possible form of support for future energy projects. In the UK, this model can be particularly replicable to high-demand sites and roof-top solar projects. As has been previously mentioned, the terms of the PPA have decreased in recent years and therefore, this approach is not economically viable under current UK legislation.

12% of respondents suggested that private wire supply may support conventional CRE projects (Table 5.3). In fact, two survey respondents reported that they are in the process of planning to develop a private wire supply. This model enables decentralised energy projects to sell their electricity directly to commercial or domestic customers without transmitting through a public network (Hall and Roelich, 2015). There are few examples of this model in the UK, with one of them being the Woking Borough Council (Energy Saving Trust, 2008). Establishing the private wire supply model can be very challenging for voluntary-based community energy organisations due to the significant capital investment required for cabling, the challenges involved in identifying suitable customers, and the complexity of legalisation.

Among respondents, 11% suggested Energy Service Companies (ESCos) could help support the future development of localised energy generation. As an ESCo model would require a licence or private wire network to supply electricity, it is particularly suitable for local authorities and potentially large CRE groups (10:10 Climate Action, 2016; RegenSW and Scown, 2016b). However, in literature it has been argued that community ESCo for directly supplying electricity under the current market regulation is in experimental stage and consequently, would require active support from Ofgem and a senior supplier. Any withdrawal of any of this support would be detrimental to the project and this would be one of the main threats to this model (10:10 Climate Action, 2016).

12% of groups in the study suggested local aggregation and Demand Side Response (DSR) models could provide an opportunity to develop localised energy projects in the future. Local aggregation and DSR models would be appropriate for large community energy projects and local authorities, and potentially suitable for small community energy organisations. The DSR may provide opportunities for CRE projects in constrained areas to become connected to the grid, consequently reducing grid connection costs. The key barrier to these models is managing to engage customers sufficiently and handling the complexity which is involved in switching energy supplier. There have been a few trial examples in the UK, with one being the Sunshine Tariff which was not successful under current (2016) UK legislation (See section 2.9.1.7 in CHAPTER 2).

5.5 Evaluating the Consistency between the Findings from the Part II Survey and the Semi-structured Interviews

The interview results have confirmed the reliability of the survey results and provided a qualitative understanding of the challenges facing CRE projects after FIT reduction. These results also provided updated data on the future activities of CRE projects. For example interview results revealed that, two out of five groups who reported that they are planning to undertake renewable heat projects were unable to deploy their projects due to the multiple challenges. One of these two CRE groups stated that the complexity of renewable heat projects compared to renewable electricity and a lack of engagement of community and residents of host buildings to be involved in community-owned renewable heat projects were the main barriers in developing these projects.

"*Our renewable heat projects cannot compete with that of commercial developers for two main reasons: firstly commercial developers can offer more attractive PPA prices to the community than CRE groups. Secondly, heat projects are more complex than renewable electricity projects and required more technical expertise, therefore, commercial developers are more capable of delivering these projects than CRE groups*".

Overall, conducting interviews enabled this study to capture an empirical understanding of the barriers that faced to CRE sector after RE policy changes and explore areas that the survey did not cover.

5.6 Conclusion

This chapter provided robust evidence on the recent activities and challenges of the CRE sector following the curtailment of RE support mechanisms.

The recent policy uncertainty has been extremely disadvantageous to many CRE projects, predominantly solar PV schemes. As community energy projects are not broadly diffused in the UK, they are very vulnerable to change in Government policy (Nolden, 2013a; Seyfang et al, 2013). Furthermore, out of those groups that were undertaking new projects, only a few large organisations were experimenting and innovating models for further development, when the majority focused on surviving rather than developing. This chapter also critically analysed the potential approaches for the future development of the CRE sector from community energy representative perspectives. However, this study identified to date there is no established business models for any of these approaches.

Based on the existing CRE business structure, community perspectives, and with current regulation and available revenue streams, this study identified that a business model of solar PV alongside battery storage can be implemented to overcome the dependency of CRE projects on public subsidies. Additionally, it can potentially play a vital role in the transition of the electricity market and assist future development of CRE projects increasing grid reliability in areas where there is high RE penetration. Consequently, the next chapter investigates the financial viability of combining electricity storage and solar PV in order to provide demand-side response and to form a practical model for the community-owned solar PV projects in post-subsidy conditions. This study focuses particularly on community-based Solar PV since it has been highlighted that the recent policy uncertainty has been extremely disadvantageous to predominantly solar PV schemes.

CHAPTER 6 BREAKTHROUGH WITHOUT FIT

6.1 Introduction

Based on the existing CRE business structure, community perspectives, and with current regulation and available revenue streams, this study identified that RE generation in particular solar PV alongside battery storage can be implemented to overcome dependency of CRE projects on public subsidies for the viability of their projects. However, this study showed that there is a lack of an established business model for integrating community-owned solar PV with storage in the UK.

This chapter investigates and analyse whether the integration of solar PV and electricity storage can be structured to provide additional service in the form of demand-side response, enabling peak shaving and electricity balancing services and, thus deliver a feasible and financially viable model for community-owned solar PV projects after FIT reduction. The approach involved using SAM (introduced in CHAPTER 3), as a simulation tool to run a discounted cash flow and techno-economic analysis.

This chapter encompasses three main parts; in the first part, the financial viability of the current community-owned solar business model with reduced FIT scheme quantitatively evaluated. This analysis provides a quantitative understanding of the techno-economic structure and viability of current community-owned solar projects after the recent changes to FIT rate forming a baseline which allows assessment of the alternative business models. Furthermore, it validates, the empirical evidence of the economic challenges faced by community-owned solar projects (presented in CHAPTER 5).

The second part of the results section, critically investigates the most promising case, that of battery storage. Different sizes of PVs combined with battery storage, and different operating modes have been simulated for a non-domestic building under different economic conditions. The final part proposes a promising innovative alternative business model for the development of community-owned solar projects in the post- subsidy condition.

6.2 Baseline Evaluation of the Existing Community-owned Solar Business Model under Current FIT Rate

This section quantitatively evaluates the feasibility of current community-owned solar projects with reduced FIT to allow for an assessment of alternative business models. As mentioned in CHAPTER 4 the most commonly used business model among CRE projects was a community-owned solar financed business model. Under this model, community organisations lease a roof from community buildings to install rooftop solar PV, but ownership of the technology and revenue streams (FIT) stays with the CRE organisation. This model allowed community host buildings to use and buy locally generated electricity through the PPA at a lower price (between £0.05 and £0.07 per kWh) than the current national grid. Under this model, the primary income of community-owned solar projects was the direct sale of electricity through PPA and receipt of FIT generation and export income (Figure 6.1).

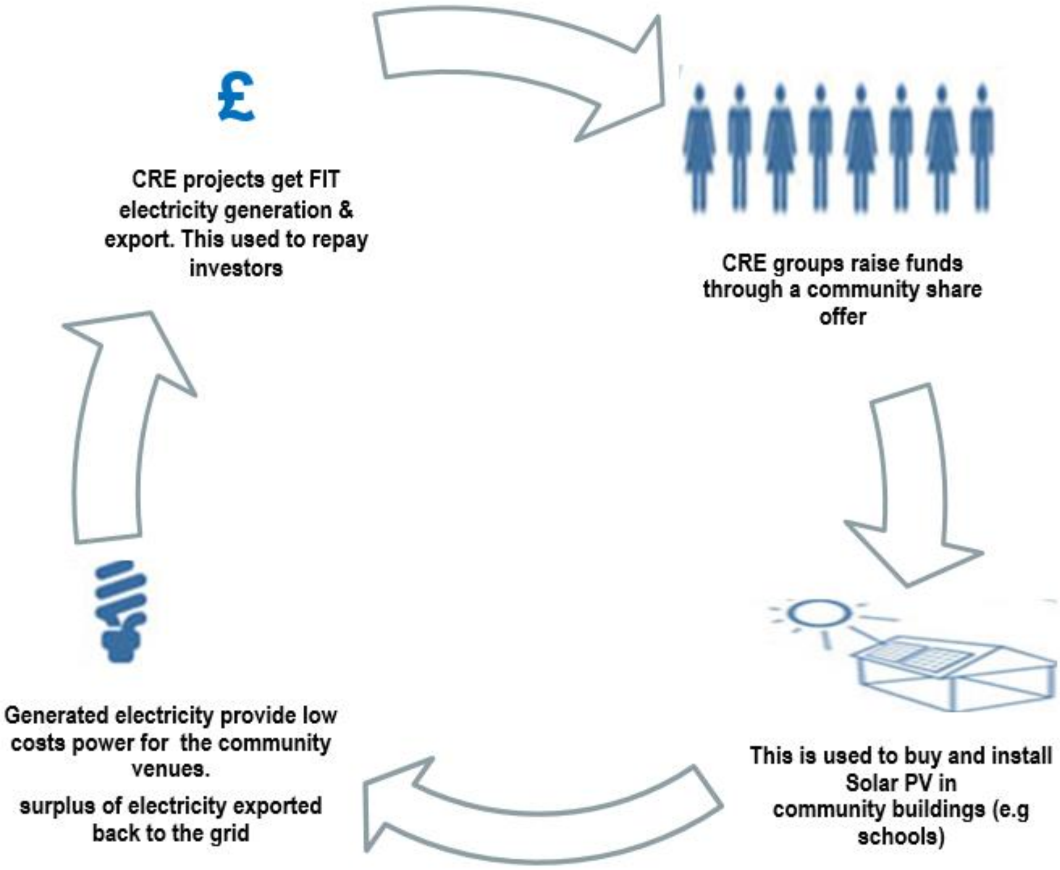

Figure 6.1 Typical Community-owned Solar Business Model Structure

6.2.1 System Definition

The building in the study is located in London, England and a standard hourly building electrical load profile has been accessed for a high school building from the UK Energy Research Council's (UKERC) electricity user profile (UKERC, 2013). The building has a peak load of 22.8 kW and an annual demand of 53,862.69 kWh (Figure 6.2).

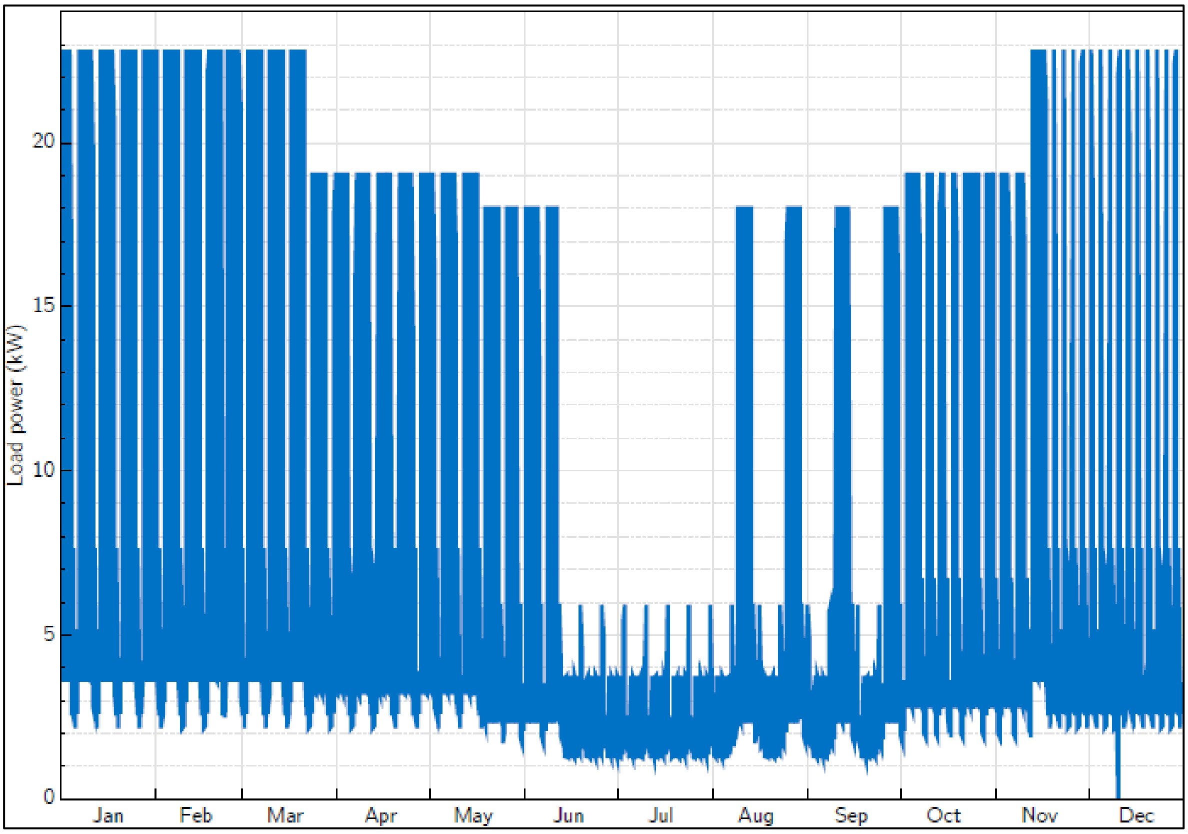

Figure 6.2 Building Load Profile for School Building Based on UKERC (2013)

For this building, 34 kW and 70 kW solar PVs (named as scenario A and scenario B respectively) have been modelled in order to investigate financial viability of existing CRE business model under two different FIT payment rate (10-50 kW rate and 50-250 kW rate).

The study uses SAM software (developed by National Renewable Energy Laboratory) and sub-hourly solar Irradiation to predict PV generation.

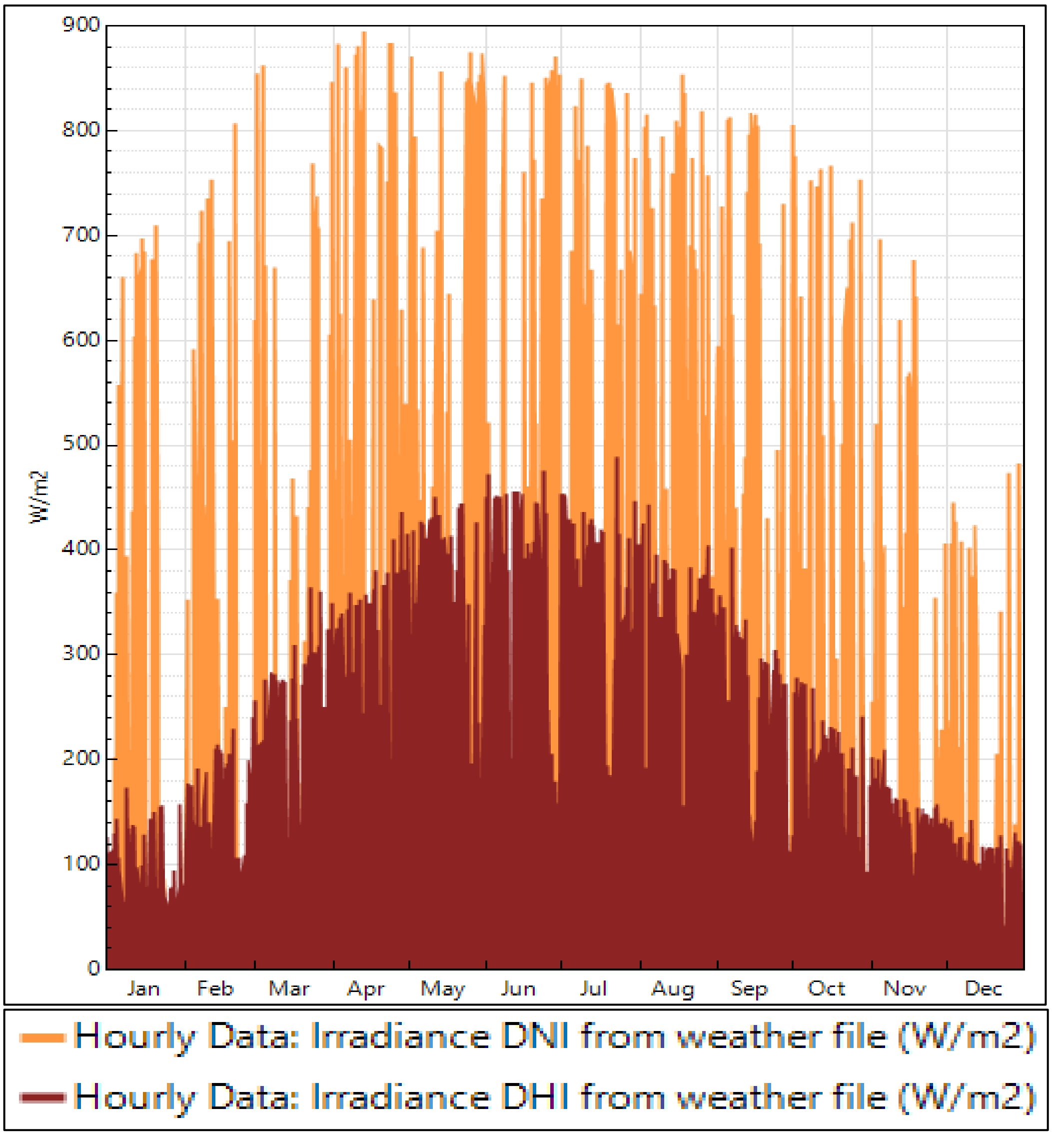

Figure 6.3 Solar Irradiance for London Gatwick between 1983 and 2000 (National Renewable Energy Laboratory, 2005)

The weather data are taken from long-term historical data from 1983 to 2000 at weather stations located in Gatwick, UK. Figure 6.3 presents the hourly irradiance for the site including Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DHI). SAM uses the sub-hourly weather data to estimate PV generation (DiOrio et al., 2015). Based on sub-hourly solar irradiation data (Figure 6.3) it has been estimated that 34 kW solar PV (named as Scenario A) in the first year will generate 34,243 kWh electricity, and 70 kW solar PV (named as Scenario B) will generate 68,249 kWh electricity (Table 6.1).

Table 6.1 Key System Parameter for Quantitative Evaluation Exisiting Community-owned solar Business Model

System Component	Parameter	Scenario A	Scenario B
Site Specification	System Location	London	London
	Building Annual Demand	53,862.69 kWh	53,862.69 kWh
	Building Peak Demand	22.84 kW	22. 84 kW
Solar PV System Design	Total Install capacity	**34 kW**	**70 kW**
	Annual Energy Production	**34,243 kWh**	**68,249 kWh**
	Array Orientation	Fixed	Fixed
	Tilt (deg)	35	35
	Azimuth (deg)	180	180
Solar Panels	Cell Type	Multi Crystalline Silicon	Multi Crystalline Silicon
	Nominal Efficiency (%)	15.92 %	15.92 %
	Degradation	5%	5%
	Total Number of Modules	**140**	**276**
	Total Module Area	**225.5 m^2**	**446.4 m^2**
	Solar Lifetime	20 years	20 years
Inverter	Power rating	**34 kW**	**70 kW**
	Efficiency	98%	98%
	Inverter Lifetime	15 years	15 years

6.2.2 Financial Analysis

The following sections provide an insight into the different economic and financial metrics which have been used in this chapter to evaluate economic feasibility of the current community based solar projects and to investigate financial viability of integrating electricity storage with solar PV to form a viable business model for the Community-owned solar PV.

It should be noted that SAM produces all financial result in USA dollars ($) and therefore, all results have been converted to sterling pounds (£) using the conversion rate of $1= £0.75 (XE Currency, 2018).

6.2.2.1 Net Present Value (NPV)

NPV measures the economic feasibility of the project that includes both revenues and costs, therefore, for the project to become financially viable, it should have positive NPV.

The NPV has been used for the discount cash flow analysis in this study; the NPV is combined with different economic scenarios for electricity prices and PV annual degradation and inverter replacement cost to produce yearly cash flow for the lifetime of the PV system.

The NPV is calculated using equation 6.1:

$$NPV = \sum_{n=0}^{N} \frac{C_n}{(1+d\ nominal\ )^n} \tag{6.1}$$

Where,

$C_n =$ After tax cash flow

$n =$ Number of years analysed

$d_{nominal} =$ refers to the discount rate with the inflation rate

$N =$ Analysis period and project lifetime

The NPV was calculated based on the nominal discount rate which calculates the value of discount rate and the inflation rate using equation (6.2):

$$Nominal\ Discount\ Rate = (1 + Real\ Discount\ Rate) \times (1 + Inflation\ Rate) - 1 \tag{6.2}$$

For the NPV calculation, the discount rate is the primary consideration factor. For community-owned solar projects which are mostly financed by community investors through a community share offer, the discount rate should be the same as or higher than the target for the return on investors share. The community-owned solar projects in the study had commonly return on equity/investment of between 4.5% (Exeter Community Energy, 2017; South East London Community Energy, 2016). This compares with 3.5% social investment return ‘ the green book’ by the UK Government (Lowe, 2008). Subsequently, cash flow analysis has been run with real discount rate of 4.5% and inflation rate of 2.5% (which is equal nominal discount rate of 7%) in order to evaluate a feasibility of the existing community-owned solar projects in the UK.

6.2.2.2 The Levelized Cost of Electricity (LCOE)

The LCOE presents the total project lifecycle costs, and it aims to provide a comparison between different technologies, with different project size, capacities and capital costs. It is the present value of projects costs, indicated in pound per kilowatt hour (£/kWh) of electricity produced by the system over its lifetime. The LCOE also can be referred to as the minimum cost at which electricity can be sold to achieve breakeven point over the lifetime of the project (Lai and Mcculloch, 2017). Usually, the LCOE is used for comparison between different technologies or considering grid parity for developing renewable technology. Grid parity occurs when LCOE of alternative source energy production is equal or at a same price of the price of purchasing power from grid. In this study, the LCOE has been used for assessing the grid parity of community-owned solar projects.

$$LCOE = \frac{-C_0 - \frac{\sum_{n=1}^{N} Z\,n}{(1+d_{nominal})^n}}{\frac{\sum_{n=1}^{N} Qn}{(1+d_{real})^n}} \quad (6.3)$$

Where,

C_0= the project equity/capital investment amount

Z_n = The annual project costs including; installation, operation and maintenance, financial costs and fees

Q_n = Electricity generated by the system in year n, this value calculated based on the weather data and the system performance parameter (such as degradation rate)

N = Analysis period and lifetime of the project

d_{real} = refers to the discount rate without the inflation rate

$d_{nominal}$ = refers to the discount rate with the inflation rate

The calculation of LCOE also depends on the different parameters; including installation and operating costs and financial parameters (including, loan term, loan rate, inflation, discount rate, inflation rate and incentives).

6.2.2.3 Internal Rate of Return (IRR)

IRR has been considered for financial evaluation of community ownership solar PV because it’s one of the most meaningful tools for investors to measure profitability and is the most commonly used method to calculate the rate of return (Rogers & Duffy, 2012; Talavera et al., 2010).

IRR is equal to:

$$NPV = \sum_{n=0}^{N} \frac{Cn}{(1+IRR)^n} = 0 \quad (6.4)$$

Where

N= Analysis period and project lifetime

C_n= After tax cash flow

6.2.2.4 Payback Period (PP)

The payback period is referred to the length of time which is required to cover the cost of an investment and can be calculated using equation (6.5):

$$PP = \frac{Cost\ of\ the\ investment}{Annual\ net\ cash\ flow} \tag{6.5}$$

The payback period has been considered for financial evaluation of privately owned solar and storage projects. It is normally a key determinant of whether to undertake the project, as longer payback periods normally are not feasible and desirable for investment.

6.2.3 Financial Parameters: Cost Assumption and Incentives

The ET Solar Industry panel, ET-P660255BB, a Multi Crystalline Silicon cell with an efficiency of 15.92% was considered as baseline system hardware. The Multi Crystalline Silicon (c-Si) solar panels were selected as they are less expensive than Mono-c-Si solar panels. Baseline costs for the PV system are taken from KPMG report prepared for the Renewable Energy Association (REA) (KPMG LLP, 2016). According to this report, Capex for the commercial solar PV system is 900 £/kW, excluding grid connection costs (KPMG LLP, 2016).

Table 6.2 presents all other key financial parameters that have been used to run techno-economic simulations. It should be noted that for the existing community-owned solar PV projects analyses have been run over 20 years based on the lifetime of solar PV.

Table 6.2 Key Financial Parameters

Parameter	Value
Project Lifetime	20
Investment Interest Rate	4%
Inflation Rate	2.5%/year
Real Discount Rate	4.5%
Nominal Discount Rate	7%

6.2.4 Financial Performance Existing Solar Project under Current FIT Rate

A series of financial analyses have been run with two different sizes of PV (34 kW and 70 kW named as Scenario A and Scenario B respectively) to evaluate the financial viability of conventional community-owned solar projects under current FIT rate. For these analyses it has been assumed that the CRE project is eligible to receive 2017 FIT generation rate for 34 kW (£0.0396/kWh) and 70 kW (£0.0207/kWh) and export rate (£0.0524/kWh) (Ofgem, 2017). Also, it has been assumed that the CRE group sells generated electricity to the host buildings for £0.07 per kWh (through PPA).

For the income calculation, it has been assumed that 60% of the generated electricity by solar PV system goes to service building demand, which means that the CRE project sells generated electricity to the host owner through a PPA. The surplus electricity will be sold back to the grid based at FIT export rate.

These analyses indicated that under the current FIT, the conventional CRE projects are not economically viable and result in negative NPV (Table 6.3). These results confirmed and validated the empirical results presented in CHAPTER 5.

Table 6.3 Metric Value for Conventional Community-owned Solar with Reduced FIT and Existing PPA £0.07

Component	Scenario A, with current PPA £0.07	Scenario B, with current PPA £0.07
Annual Energy Yield (Year 1)	34,243 kWh	68,249 kWh
Capacity Factor (Year 1)	10.70%	11.30%
Performance Ratio (Year 1)	0.84	0.84
PPA Price (Year 1)	0.07 £/kWh	0.07 £/kWh
LCOE	0.14 £/kWh	0.12 £/kWh
IRR	2.65%	1.01%
NPV	**-£19,564**	**-£53,196.750**
Capital Cost	£67,715	£131,902
Equity	£67,715	£131,902

Then, in order to investigate, how the conventional CRE business model can be structured to become financially viable with new FIT rate, eight parametric analyses have been run for Scenario A and Scenario B with the different discount rates between 4% and 5.5% (Table 6.4 and Table 6.5).

These analyses indicated that in order for the conventional CRE business model to become financially viable with new FIT rate, PPA should charge as much as or even more than the grid. For example, Table 6.5 shows that for a 70 kW solar PV charges should be between £0.15 and £0.18 per kWh.

Table 6.4 Financial Evaluation of 34 kW Community-owned Solar with Reduced FIT Rate and Different Discount Rate

Component	Scenario A_1 with discount rate 4%	Scenario A_2 with discount rate 4.5%	Scenario A_3, discount rate 5%	Scenario A_4 discount rate 5.5%
Annual Energy Yield (Year 1)	34,243 kWh	34,243 kWh	34,243 kWh	34,243 kWh
Capacity Factor (Year 1)	10.70%	10.70%	10.70%	10.70%
Performance Ratio (Year 1)	0.84	0.84	0.84	0.84
PPA Price (Year 1)	**0.13 £/kWh**	**0.14 £/kWh**	**0.20 £/kWh**	**0.22 £/kWh**
LCOE	0.14 £/kWh	0.15 £/kWh	0.16 £/kWh	0.17 £/kWh
IRR	7%	7.50%	8%	9%
NPV	**£2,146**	**£2,030**	**£1,919**	**£4,343**
Capital Cost	£67,715	£67,715	£67,715	£67,715
Equity	£67,715	£67,715	£67,715	£67,715

As indicated in Table 6.4 and Table 6.5 even with the higher PPA, the NPV is still very low. Therefore, it would not provide an attractive financial incentive for CRE organisations and the site owners.

Table 6.5 Financial Evaluation of 70 kW Community-owned Solar with Reduced FIT Rate and Different Discount Rate

Component	Scenario B_1 with discount rate 4%	Scenario B_2, with discount rate 4.5%	Scenario B_3 with discount rate 5%	Scenario B_4, with discount rate 5.5%
Annual Energy Yield (Year 1)	68,249 kWh	68,249 kWh	68,249 kWh	68,249 kWh
Capacity Factor (Year 1)	11.30%	11.30%	11.30%	11.30%
Performance Ratio (Year 1)	0.84	0.84	0.84	0.84
PPA Price (Year 1)	**0.15 £/kWh**	**0.16 £/kWh**	**0.17 £/kWh**	**0.18 £/kWh**
LCOE	0.12 £/kWh	0.13 £/kWh	0.13 £/kWh	0.14 £/kWh
IRR	7%	7.50%	8%	9%
NPV	**£4,266.750**	**£4,037.250**	**£3,816.750**	**£8,635.500**
Capital Cost	£131,902	£131,902	£131,902	£131,902
Equity	£131,902	£131,902	£131,902	£131,902

6.2.5 When can the Existing Community-owned Solar PV Projects Potentially Reach Grid Parity?

Table 6.6 shows that currently, community-owned solar projects are far from grid parity which means the LCOE, for producing electricity by solar PV is still higher than purchasing electricity from the grid. As previously mentioned LCOE refers to the minimum cost at which electricity can be sold to achieve the breakeven point over the lifetime of the project.

Table 6.6 Metric Value for Conventional 70 kW Community-owned solar PV Projects without FIT

Component	Value for 70 kW Community-owned Solar PV
Annual Energy Yield (Year 1)	68, 249 kWh
Capacity Factor (Year 1)	11.30%
Performance Ratio (Year 1)	0.84
PPA Price (Year 1)	£0.27
LCOE	**0.21 £**/kWh
NPV	**£4,169**
IRR	7%
Capital cost	£131,902
Equity	£131,902

To investigate when the conventional community-owned solar projects could potentially become self-sustaining a series of parametric analyses of annual cost reduction in the total installed cost of community-owned solar projects has been run for 70 kW solar PV.

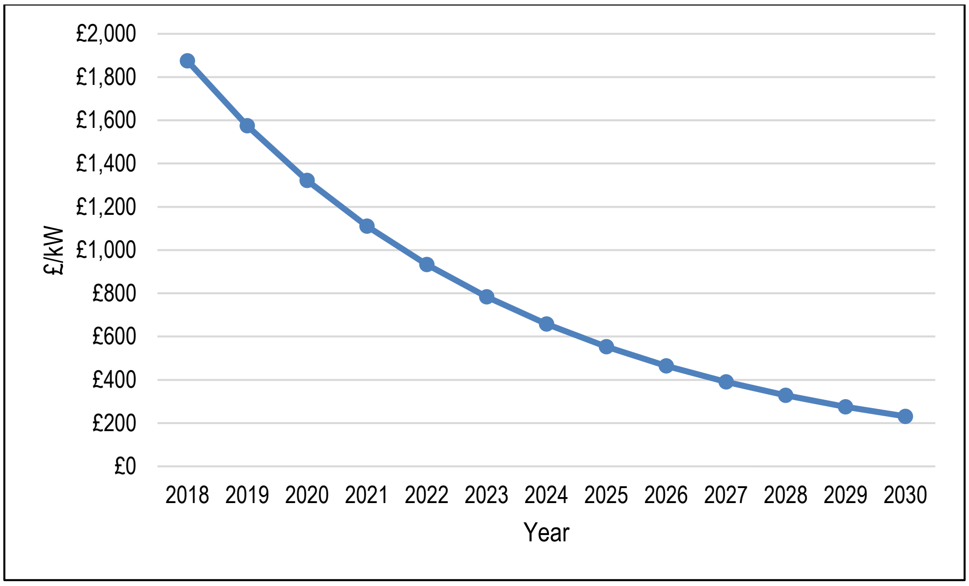

Figure 6.4 Solar PV System Cost Reduction between 2018 and 2030

Based on the KPMG LLP, (2016) report an average annual cost reduction of the 16% for the total installed cost per capacity (£/kW) has been modelled (Figure 6.4).

Based on the assumption of 16% cost reduction per annum in solar system costs (Figure 6.5) and 3% increase in electricity prices community-owned solar will reach grid parity in 2021, with LCOE of £0.12 kWh which means cost of producing electricity from solar would be cheaper than grid without help of any subsidies.

However, the existing community-owned solar business model will become financially viable and attractive by 2025 without any FIT payment. This means that if the price of electricity from grid increase from £0.14 per kWh (for small business) to £0.17 per kWh in 2025, CRE projects can produce electricity without any incentive and directly sell it to host owner £0.12 per kWh (Figure 6.5).

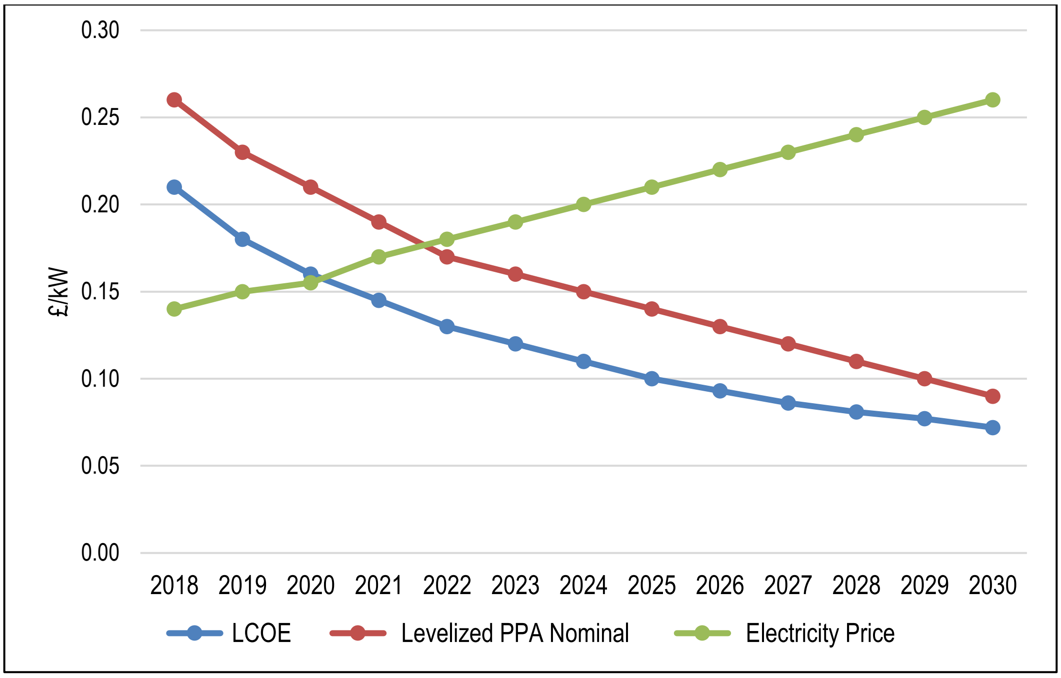

Figure 6.5: 70 kW Community-owned Solar project LCOE Versus Electricity Prices in the UK

6.2.6 Weaknesses of the Current Community-owned Solar Project Business Model

Under the current community-owned solar project business model, the majority of these solar projects are installed on schools rooftops. Ideally schools should use all electricity generated to fully benefit from solar PV system although, during weekends and summer holidays (peak time for solar generation) when schools are closed because the electricity is not used, it is sold/exported back to the grid and bought back at twice the price by someone else in the community. Consequently, when current community-owned solar projects reach grid parity there are still some questions about the economic sustainability of these projects. Under the existing model the community is not getting the true value for its investment or retaining the income locally also, there are still electricity losses through export of electricity to the grid even though it has been generated locally.

This study clearly emphasised the importance of business model innovation for CRE projects. Integrating solar PV alongside electricity storage can potentially overcome challenges faced CRE projects and the drawbacks of conventional models. However, a business model for integrating community-owned solar with storage has not been established in the UK. Therefore, in the following sections, this study investigates and analyses whether the integration of solar PV and electricity storage can be structured to provide additional service in the form of demand-side response, enabling peak shaving and electricity balancing services and, thus deliver a feasible and financially viable model for community-owned solar PV projects after FIT reduction.

6.3 Techno-Economics Assessment of Battery Storage as A Potential Business Model

This section presents the results of techno-economic simulations of integrating solar PV with electricity battery storage. The first sub-section gives an overview of the potential source of storage revenues followed by techno-economic results of the integration of behind meter battery storage and solar PV in non-domestic buildings under the different economic conditions (Scenario 1 and 2); finally, a new business model for community-owned solar projects is presented in Scenario 3.

6.3.1 Potential Revenue and Saving Opportunities of Storage

Integrating storage with renewable energy generation offers potential saving opportunities for businesses and non-domestic buildings to reduce their energy costs. Based on the flexibility of services that storage can deliver to energy system services it can also create revenue streams for developers (Regen SW, 2016).

These services can be categorised as the follows:

I. Balancing (Response): The ability to respond in millisecond to minute to grid or price signals
II. Reserve: The ability to store electricity and discharge it when needed
III. Price and Time shift: the ability to store electricity at off-peak rate, discharge at times of peak demand to reduce expensive demand charges, referred as peak shaving

Balancing and reserve revenues are typically referred to as ancillary services revenues. The term of ancillary services is used to refer to different operations including voltage control, load and frequency regulation and reserve replacement which helps to maintain grid stability and security (Energy UK, 2017).

Potential sources of revenue and saving opportunities of this model include;

I. Peak Shaving, consumers reduce their electricity demand during peak price period
II. Transmission Use of System (TNUoS) and Distribution Use of System (DUoS) cost avoidance
III. Provide Demand Side Response (ancillary) service

Demand Side Response (DSR) involves fluctuations in electricity demand in response to changing electricity prices or incentives (Behrangrad, 2015). DSR enables end users to change their demand of electricity from the grid (or other output), as a result of signals from the current supplier, infrastructure or system operator (Gillich et al., 2017).

The following sections explain the potential savings on non-domestic electricity bills by avoiding network charges as well as the potential to generate revenue by providing services to maintain grid stability and security.

6.3.2 Transmission Network Use of System and Distribution Use of System Cost Avoidance

DUoS charges apply to every connection to the distribution network and occur at the level of local DNO. The DUoS charge usually accounts for approximately 14% of a total of 27% of network costs of non-domestic customers electricity bills (Figure 6.6). The network cost is usually calculated based on customers maximum electricity consumption during the peak time prices (customers maximum half-hourly peak power) (Scottish and Southern Energy Power Distribution, 2017).

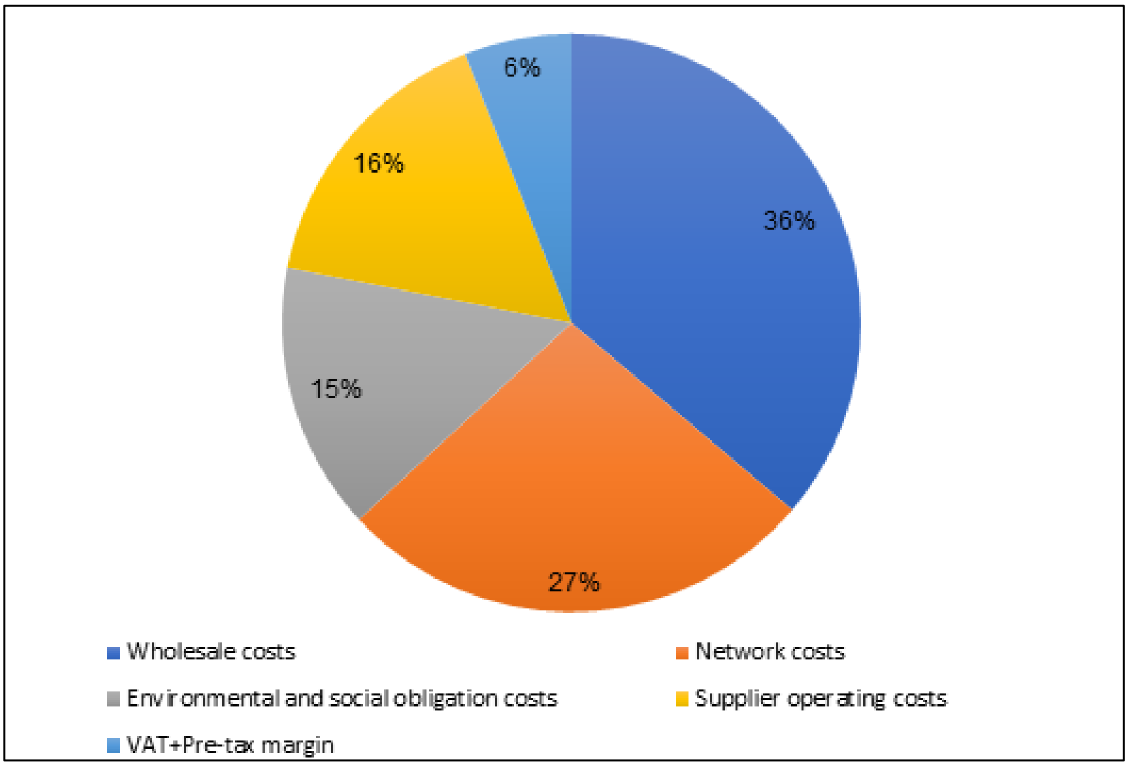

Figure 6.6 Breakdown Non-Domestic Electricity Bill In The UK (Ofgem, 2015a)

As Table 6.7 shows, the DUoS unit charge is divided into three time-of-use band periods Red, Amber, and Green. These charges are usually different and depend on the type of meter (half-hourly or non-half-hourly), voltage type (high or low), time of use and location (region) and supply company (Eonenergy, 2018).

Table 6.7 DUoS System Time Bands for Half Hourly Metered Properties (London Power Network, 2018)

Time periods	Red Time Band	Amber Time Band	Green Time Band
Monday to Friday (Including Bank Holidays) All Year	11:00 - 14:00 16:00 - 19:00	07:00 - 11:00 14:00 - 16:00 19:00 - 23:00	00:00 - 07:00 23:00 - 24:00
Saturday and Sunday All Year	---------------	---------------------	00:00 - 24:00

The National Grid charges suppliers (and hence end users) for using the transmission network. The rate of TNUoS is location-specific and therefore based on the transmission demand tariff of the region (National Grid, 2016). The TNUoS are based on three separately observed peaks of the system across the year. These peak demands are measured over half hour intervals by National Grid and referred to as Triads. These typically occur in winter between the months of November and February in the late afternoon between 16:00 and 19:00. If an end user with storage capability can reduce their demand during the Triad period then they can reduce their TNUoS charges (National Grid, 2016). In order to access TNUoS avoidances the storage provider must be a partner with an energy supplier (Gillich et al., 2017).

6.3.3 Ancillary Services

In addition to providing saving by avoiding network charges through peak shaving, electricity storage can potentially generate income by providing ancillary services (DSR) based on the size and type of storage. These include, Firm Frequency Response (FFR), Frequency Control by Demand Management (FCDM), Short Term

Operating Reserve (STOR) and potentially Demand Turn UP (DTU) just to name few (Table 6.8). However, among all these Ancillary revenues, this study identified FFR and STOR are the most potential revenue streams and avoiding network charges as the most potential saving opportunities for behind matter storage in non-domestic buildings and CRE projects.

6.3.3.1 Firm Frequency Response (FFR)

This service provides a dynamic/non-dynamic response to changes in frequency in order to maintain overall grid frequency at 50 Hz. The service is offered on a monthly basis and tariff rates vary depending on the service level. The FFR can provide revenue for battery applications that can deliver a minimum 10 MW response within 10 seconds (primary) or in 30 seconds (secondary) although this capacity can also be aggregated. The National Grid buys FFR service through a competitive tender. The service is available in short-term contracts typically between 6 to 23 months (National Grid, 2018) and runs 24/7; the service provider is paid based on availability (£/hour).

6.3.3.2 Short Term Operating Reserve (STOR)

This service is needed when the actual demand on the grid is greater than predicted demand. According to Power Responsive, (2016), this service is suitable for Battery Storage, Pump Hydro. The STOR provider must be able to deliver: i) Minimum of 3 MW generation or steady demand reduction ii) Deliver full MW within 240 minutes or less from receiving instruction from National Grid iii) Deliver full capacity for at least 2 hours when receiving instructions and iv) Be able to deliver at least 3 times a week. However, these requirements for STOR can be met by aggregation from more than one site.

Table 6.8 Potential Revenue Streams, Source Complied from (KPMG LLP, 2016; Power responsive, 2016; Regen SW, 2016)

Class of Services	Services Element	Major Revenue Stream	Definition
Price and Time Shift	Peak shaving, Maximise on site use, Bill cost management	Avoiding TNUoS charges &	Avoiding Triad between Nov- Feb
		Avoiding DUoS charges	Avoiding Red Zone price during the peak time
	Fast response	Enhanced Frequency Response	Keeping grid frequency at 50Hz
Balancing (Response) Revenue	Frequency regulation	Firm Frequency Response (FFR) &Frequency Control Demand Management (FCDM)	Provide dynamic/non-dynamic response to changes in frequency
	Voltage control	Fast Reserve	Manage frequency changes that happened in result of unexpected change in generation or demand
Reserve Revenue	Reserve	Short term operating reserve (STOR)	When actual demand greater than predicted demand
		STOR Runway	Provide STOR services for smaller load
	Power Back up	Demand Turn up	To shift demand to peak of RE generation
		Capacity Market	To secure existing and incentivise new capacity to maintain capacity margin

In the following sections, we assess the different sizes of solar PV and battery storage with the various storage operating modes under different economic conditions to create an innovative alternative business model for community-owned solar PV.

6.4 Investigating the Feasibility Combining Electricity Storage and a Solar PV under Different Scenarios

Nine techno-economic analyses have been run under three different scenarios (named as Scenario 1, Scenario 2 and Scenario 3) for two different sizes of solar PV, 56 kW and 70 kW (named as A and B respectively) to investigate the financial viability and non-technical barriers of integrating electricity storage with solar PV to form an innovative alternative business model for community-owned solar PV.

Each scenario investigates the most promising business case, specifically that of battery storage under different strategies. Each strategy is then investigated to identify the best potential application of electricity storage under different battery operating modes and economic conditions. Table 6.9, outlines a summary of the aims of all three scenarios.

Scenarios 1 and 2 investigate the feasibility of investment in combining electricity storage and a solar PV system in non-domestic buildings. Also, to gain a background understanding of how to model the revenue streams of the alternative business model.

Scenario 3 proposes an innovative alternative model for community-owned solar PV projects based on the results of Scenario 1, Scenario 2 and other sub-studies indicated in previous chapters. The following sections present results of these techno-economic analyses.

Table 6.9: Summary of all Techno-Economic Assessment Scenarios used to Evaluate the Most Promising Business Model

Definition / Sub-scenarios		Aim of the Scenario	Building Location	Building Annual Electricity Demand	Total Install Capacity of Battery	Total Installed Capacity of Solar PV	Type of Revenues and Revenue Model	Type of Project Ownership
Scenario 1	Strategy 1.1 Strategy 1.2 Strategy 1.3 Strategy 1.4	This scenario investigates the financial impact of peak shaving on up take of electricity storage in the non-domestic buildings. Under different battery operating modes (Strategy 1.1, 1.2, 1.3, 1.4).	London	53,862.69 kWh	**42 kWh**	56 kW 70 kW	Electricity bill saving via peak shaving and network charge avoidances.	Private Ownership
Scenario 2	Strategy 2.1 Strategy 2.2	This scenario evaluates the economic feasibility of integrating the behind meter electricity storage and solar PV to provide peak shaving as well as providing balancing services for the grid. Evaluating different potential revenue streams (Strategy 2.1, 2.2)	London	53,862.69 kWh	**50 kWh**	56 kW 70 kW	Electricity bill saving via peak shaving and income via providing balancing services for the grid.	Private Ownership
Scenario 3	Strategy 3.1 Strategy 3 2 Strategy 3.3	This scenario proposes an alternative business model for the UK's community-owned solar projects. Based on the result of scenario 1 and scenario 2, evaluating different potential revenue streams (Strategy 3.1, 3.2, 3.3)	London	53,862.69 kWh	**50 kWh**	56 kW 70 kW	Income via selling electricity to host buildings thorough TOUPPA ,DSR and balancing services	Community ownership / co-operative

6.4.1 Scenario 1: Integrating of Electricity Storage and Solar PV to Provide Peak Shaving

This scenario aims to investigate the financial impact of peak shaving (avoidances of DUoS and TNUoS) on integrating of electricity storage and solar PV projects on in non-domestic buildings with onsite demand.

6.4.2 System Definition

The building in the study is the same as the previous section: it is located in London, England, and has a load of 22.8 kW and an annual demand of 53,862.69 kWh as shown in Figure 6.2. For this building, 56 and 70 kW solar PV array with battery size of 42 kWh Lithium-Ion Nickel Manganese Cobalt Oxide (NMC) has been modelled (Table 6.11). This type of battery was selected as they have a longer life and would potentially reduce the number of battery replacements over the system lifetime (DiOrio et al., 2015). As a result, a technical specification similar to the Tesla Powerwall 2 (14 kWh) was used for the battery technical speciation. Table 6.11 indicates the technical details of the system for the single Powerwall pack, and for this scenario, we simulated 3×14 kWh Powerwall pack (Woollaston and Curtis, 2018).

Regarding solar PV size, it should be noted that for this building a large solar PV has been modelled to have sufficient electricity surplus for charging the battery storage.

Table 6.11: Key System Parameter for Scenario 1 (Battery technical specification complied from (Lambert, 2016)

Component	Parameter	Scenario 1A	Scenario 1B
Site Specification	System Location	London	London
	Building Annual Demand	53,862 kWh	53,862 kWh
	Building Peak Demand	22.84 kW	22.84 kW
Solar System Design	Total Installed Capacity	**56 kW**	**70 kW**
	Annual Energy Production	**56,644 kWh**	**68,249 kWh**
	Azimuth (deg)	180	180
	Tilt (deg)	35	35
	Array Orientation	Fixed	Fixed
Solar Panels	Cell Type	Multi Crystalline Silicon	Multi Crystalline Silicon
	Nominal Efficiency (%)	15.92 %	15.92 %
	Degradation	5%	5%
	Total Number of Modules	**220**	**276**
	Total Module Area	**354.4 m^2**	**446.4 m^2**
	Solar PV Lifetime	20 years	20 years
Inverter	Power rating	**56 kW**	**70 kW**
	Efficiency	98%	98%
	Inverter Lifetime	15 years	15 years
Battery	Battery Installed capacity	42 kWh (3* 14 kWh)	42 kWh (3* 14 kWh)
	Round Trip efficiency	89%	89%
	Depth of discharge (DoD)	100%	100%
	Battery Lifetime	15 years	15 years
	Maximum C Rate of Charge (per/hour)	0.5% = 2 hours	0.5% = 2 hours
	Maximum C rate of Discharge (per/hour)	0.25% = 4 hours	0.25% = 4 hours
	Time at Maximum power	4 hours	4 hours
	Battery Technology	Lithium-Ion NMC	Lithium-Ion NMC
	Round Trip Efficiency	89%	89%
	Depth of Discharge(DOD)	100%	
	Dimensions	1150 mm x 755 mm x 155 mm	1150 mm x 755 mm x 155 mm
	Weight	122 kg (269 lbs)	122 kg (269 lbs
	Operating Temperature Range	–20°C to 50°C	–20°C to 50°C
	Lifetime (assumption)	15 years or 5475 cycles	15 years or 5475 cycles
	Cost (Capex= installation costs + hardware costs+ technology cost)	529 (£/ kWh)	529 (£/ kWh)

6.4.3 PV Generation and Battery Utilisation Model

A PV generation and battery utilisation model was developed with SAM to evaluate the electricity supplied into the building from Solar and Grid. Figure 6.7 presents the hourly load data from the grid for 56 kW solar PV system to the building demands. The 56 kW Solar PV system generates annually 56,644 kWh (for the year 1) and, 70 kW solar PV system 68,249 kWh (Table 6.11).

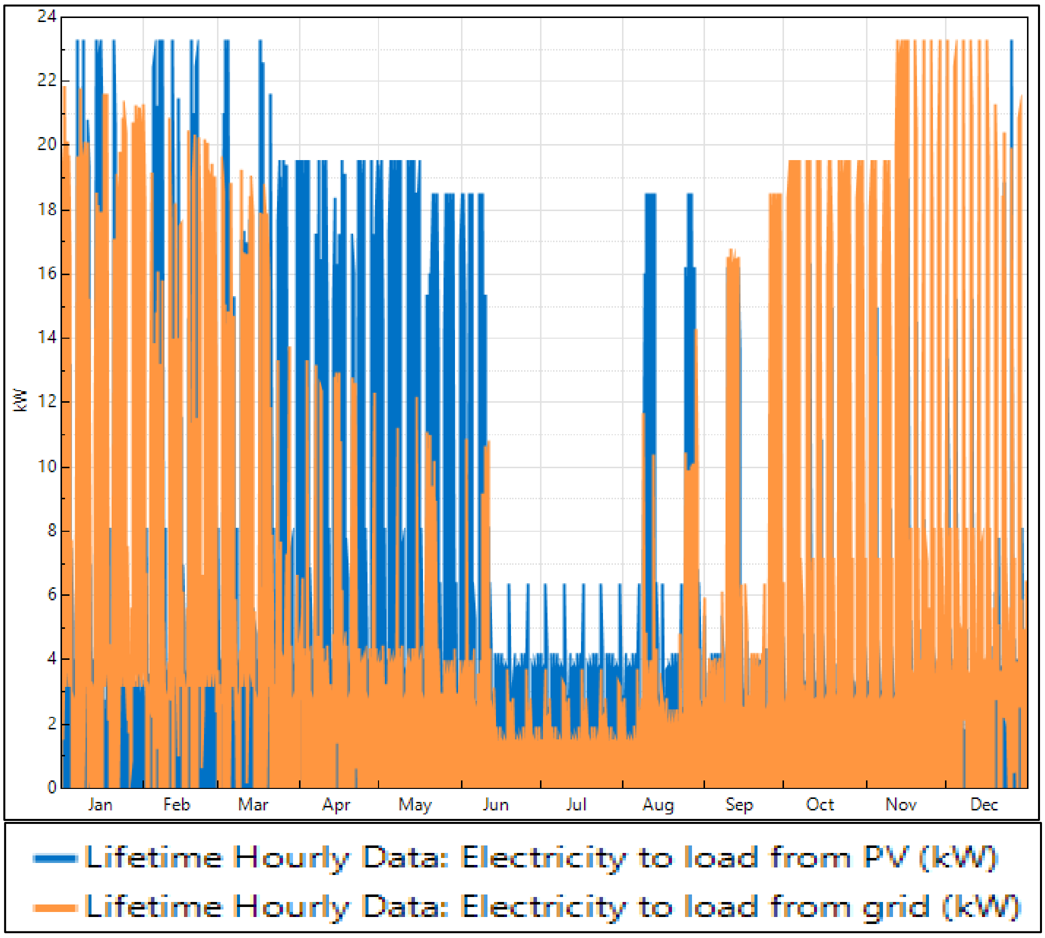

Figure 6.7: Electricity from Grid and System to Building Load for 56 kW solar PV System

6.4.4 Cost Assumption

Baseline costs for the PV system are taken from KPMG report prepared for Renewable Energy Associations (REA) (KPMG LLP, 2016). According to this report, Capex for commercial solar PV system is 900 (£/kW), excluding grid connection cost (KPMG LLP, 2016). The costs for a Tesla Powerwall 2 Lithium-Ion NMC are taken from 2018 catalogue information (Woollaston and Curtis, 2018). The UK cost for the 14 kWh Powerwall 2 is at £5,400 for technology, with £500 (including VAT) for supporting hardware and installation costs of £800 to £2,000 excluding the connection cost. For this analysis, we considered £1400 for installation cost. As a result, the battery storage Capex considered in this study is 529 £/kWh (Woollaston and Curtis, 2018).

6.4.5 Electricity Rate and Incentives

An electricity price of £0.14 per kWh was used based on the Department of Business Energy and Industrial Strategy (2018) electricity price for the small non-domestic building. The electricity price is the fully delivered price including Climate Change Levy cost and other charges except for VAT and fully inclusive of standing charges and DUoS and TNUoS.

Table 6.12: DUoS and TNUoS Charges for Half Hourly Metered Properties in London (London Power Network, 2018 ; National Grid, 2016)

Period	Time periods	Time band	Price £/kWh
Red band charges	Monday to Friday All Year	11:00 -14:00 16:00 - 19:00	0.03321 £/kWh
Amber band charges	Monday to Friday All Year	07:00 - 11:00 14:00 - 16:00 19:00 - 23:00	0.00207 £/kWh
Green band charges	Monday to Friday All Year	00:00 - 07:00 23:00 - 24:00	0.0005 £/kWh
	Saturday and Sunday All Year	00:00 - 24:00	
Triad (TNUoS)	Monday to Friday Between November and February	17:00-18:00	54.96 £/kWh

Therefore, we added a standing charge for the commercial building (£0.66 per day). Also, to capture peak time prices, DUoS charges were added to the electricity price for each time period (Business Electricity Prices, 2016; London Power Network, 2018) (Table 6.12).

Based on the Triads forecast (which, typically happens for half an hour after 17:00 in winter time), to capture Triad period charges, 1-hour TNoUS charges (£54.96) have been simulated at 18.00 between November and February (National Grid, 2016).

Table 6.13: Financial Parameters for Scenario 1

Parameter	Value
Project Lifetime	15 years
Loan Interest Rate	4%
Loan Term	15 years
Inflation Rate	2.5%/year
Real Discount Rate	4.5 %
Nominal Discount Rate	7%
Bill Escalation rate	4%

This analysis investigates the viability of the project without any FIT payment. Table Table 6.13 outlined all other financial parameters which have been used in this scenario. Analyses showed that with battery replacement costs the business model is not financially attractive due to a more extended payback period (See APPENDIX F). As a result, for the following scenarios, the techno-economic simulations and assessment have been only conducted over 15 years excluding the battery replacement.

6.4.6 Battery Charge and Discharge Schedule Strategies

Integrating behind meter storage and solar PV provide an opportunity for non-domestic buildings owner and businesses to significantly reduce their annual electricity bill through peak shaving (avoiding TNUoS and DUoS charges). In order to investigate the most promising business case, four different battery operating strategies have been simulated, Table 6.14 outlines a summary of all of these strategies.

Table 6.14: Summary of Battery Operating Strategies of Scenario 1

	Definition	Aim of the Strategy
Scenario 1	**Strategy 1.1**	To investigate the financial feasibility of using the battery to avoid TNUoS and DUoS charges in the evening.
	Strategy 1.2	To investigate the financial feasibility of charging the battery from the grid at night during off-peak price to avoid TNUoS and DUoS peak prices in the evening.
	Strategy 1.3	To investigate the financial feasibility of only using the battery at the time of Triad in winter and between October and March during Red Zone (DUoS) prices in the evening.
	Strategy 1.4	To investigate the financial feasibility of using the battery during peak power consumption in the building.

6.4.6.1 The Battery Operating Mode - Strategy 1.1

The Solar PV system was programmed to meet the building load before charging the battery. Also, the battery was programmed to charge from the surplus of generated electricity between 7:00-15:00, then to be discharged in the evening between 16:00 and 19:00 during the peak time prices (Table 6.15).

Table 6.15: Battery Charge and Discharge Schedule Strategy 1.1

Charge/Discharge Schedule	Charge/Discharge Schedule	Charge /Discharge Strategy
Jan-Dec Weekdays	7:00 -15:00	Charge from Solar PV
Jan-Dec Weekdays	16:00 -19:00	Discharge 22% each hour
Jan-Dec Weekends	7:00 -19:00	Charge from Solar PV
Jan-Dec Weekends	19:00 - 23:00	Discharge 15% each hour

The maximum state of charge for all strategies under scenario 1 was programmed as 90% with minimum state of charge of 10%, and the battery stays at charge state for minimum time 15 minutes.

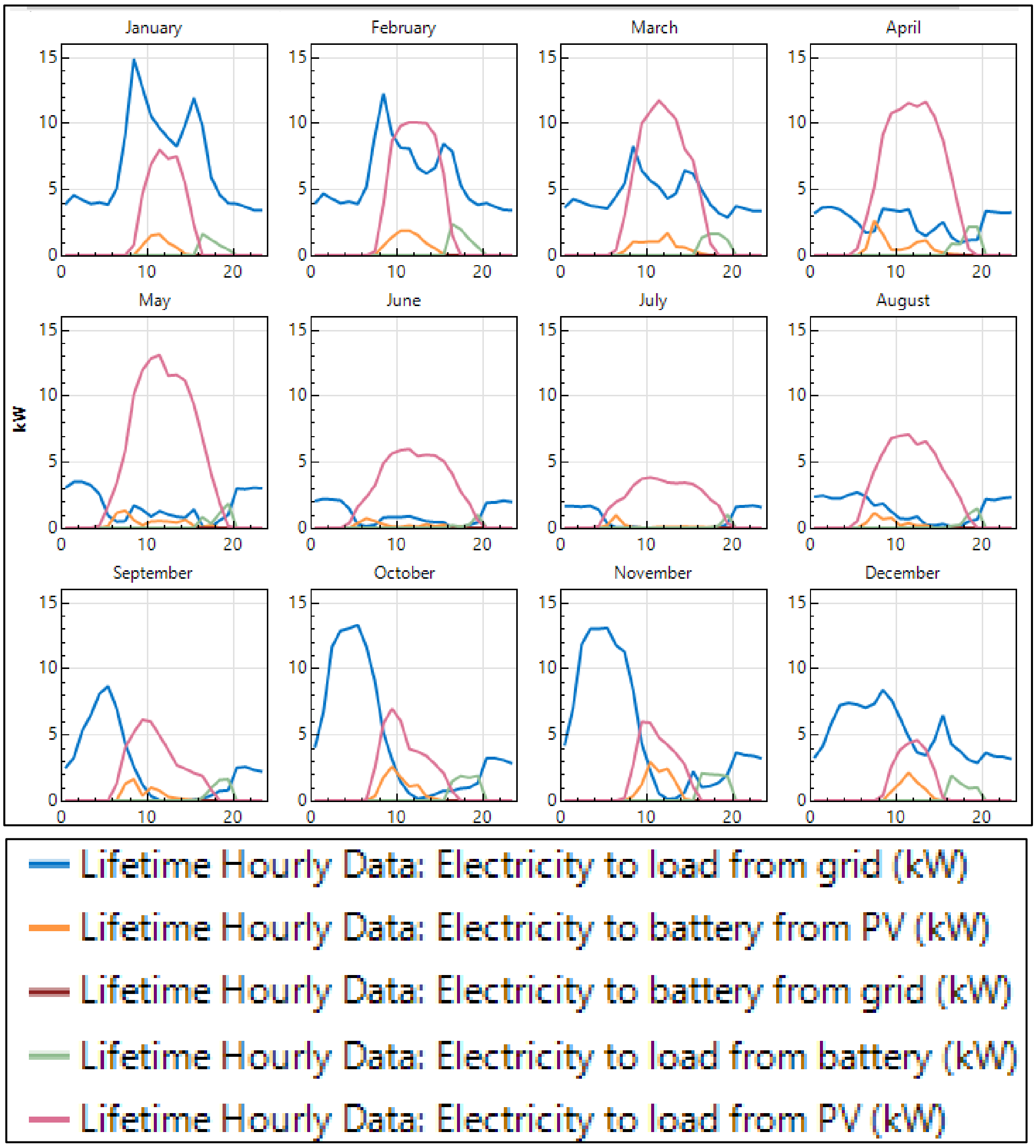

Figure 6.8: Lifetime Electricity Hourly Data for PV and Storage with Strategy 1.1

As Figure 6.8 shows based on the battery charge and discharge strategy the solar PV system throughout year initially meets building loads (pink line) and then charges the battery with surplus generated electricity (orange line).

6.4.6.2 The Battery Operating Mode -Strategy 1.2

Under the Strategy 1.2, the battery was programmed to charge from the grid between November and February at night during off-peak price between 24:00 and 3:00 in order to avoid peak time price charges in the evening (Table 6.16).

Table 6.16: Battery Charge and Discharge Schedule Strategy 1.2

Charge/Discharge Schedule	Charge/Discharge Time	Charge/Discharge Strategy
March-Oct Weekdays	7:00 -16:00	Charge from Solar PV
March-Oct Weekdays	16:00 -19:00	Discharge 22% each hour
Nov – Feb Weekdays	24:00 - 03:00	Charge from grid 100%
Jan -Dec Weekends	7:00 - 19:00	Charge from Solar PV
Jan -Dec Weekends	19:00 - 23:00	Discharge 15% each hour

Charging the battery from the grid during the winter (light green line, Figure 6.9) when the building demand is high and solar generation is low would help the battery to meet demand throughout the year.

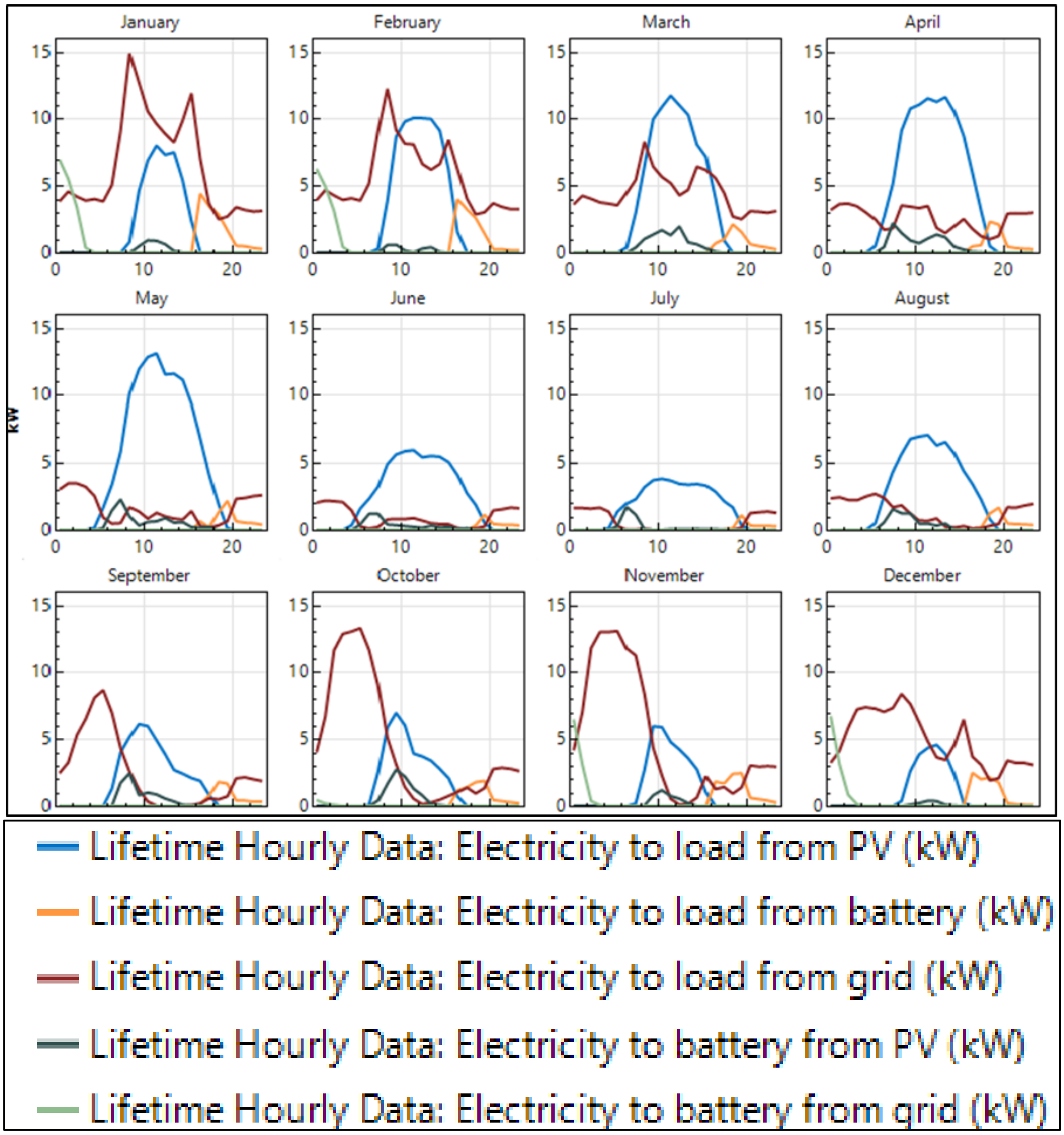

Figure 6.9: Lifetime Electricity Hourly Data for PV and Storage with Strategy 1.2

This strategy enabled the battery to provide a significant reduction in electricity consumption from the grid during peak prices. Which consequently has resulted in the higher net energy saving and reduced electricity bills dramatically compared to the system with Strategy 1.1.

6.4.6.3 The Battery Operating Mode -Strategy 1.3

Under this strategy, the battery was programmed only to be charged from surplus electricity generated from solar PV system after meeting building demands. Therefore, between November and February when solar generation is low, and building demands are high the battery storage was programmed to only discharge between 18:00 and 19:00 at the time of Triad. Also, in October and March battery was programmed to be charged during the day and discharged during Red Zone prices which are between 16:00 and 19:00 (Table 6.17).

Table 6.17: Battery Charging and Discharge Schedule Strategy 1.3

Charge/Discharge Schedule	Charge/Discharge Time	Charge/Discharge Strategy
March-Oct Weekdays	7:00 -15:00	Charge from Solar PV
March-Oct Weekdays	16:00 - 19:00	Discharge 22% each hour
Nov-Feb Weekdays	7:00 -17:00	Charge from Solar PV
Nov-Feb Weekdays	18:00 - 19:00	Discharge 90%
Jan -Dec Weekends	7:00 - 19:00	Charge from Solar PV

A system with Strategy 1.3 would result in a significant saving in electricity bills by using battery storage in the evening to avoid Triad charges between November and February and red band charges between March and October (Figure 6.10).

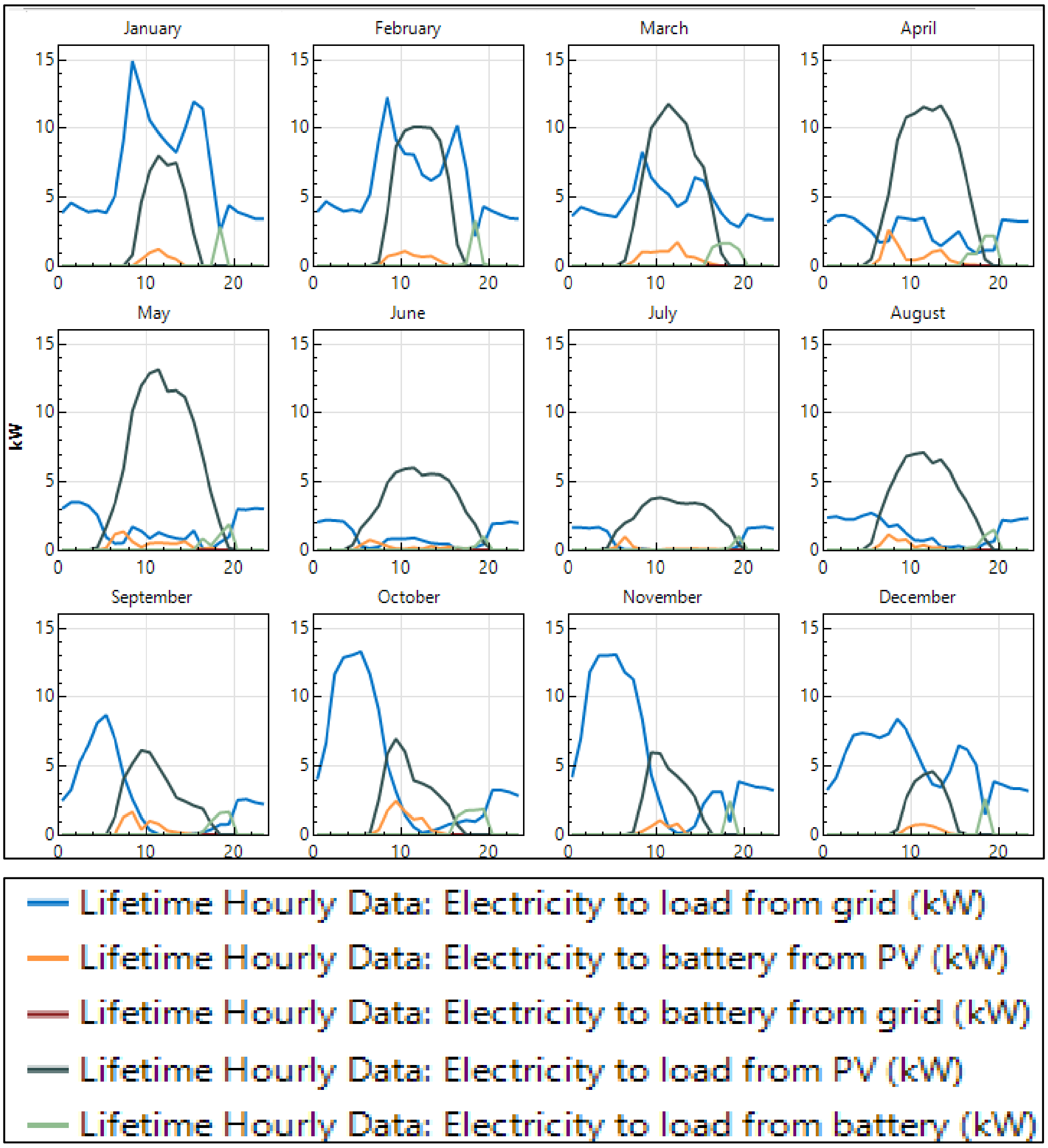

Figure 6.10: Lifetime Electricity Hourly Data for PV and Storage with Strategy 1.3

6.4.6.4 The Battery Operating Mode -Strategy 1.4

In this strategy, the battery was programmed to provide peak shaving based on building demand and operate the system to reduce grid power consumption. Under Strategy 1.4, the battery only maximised building self-consumption throughout the year during the peak electricity demand (Figure 6.11).

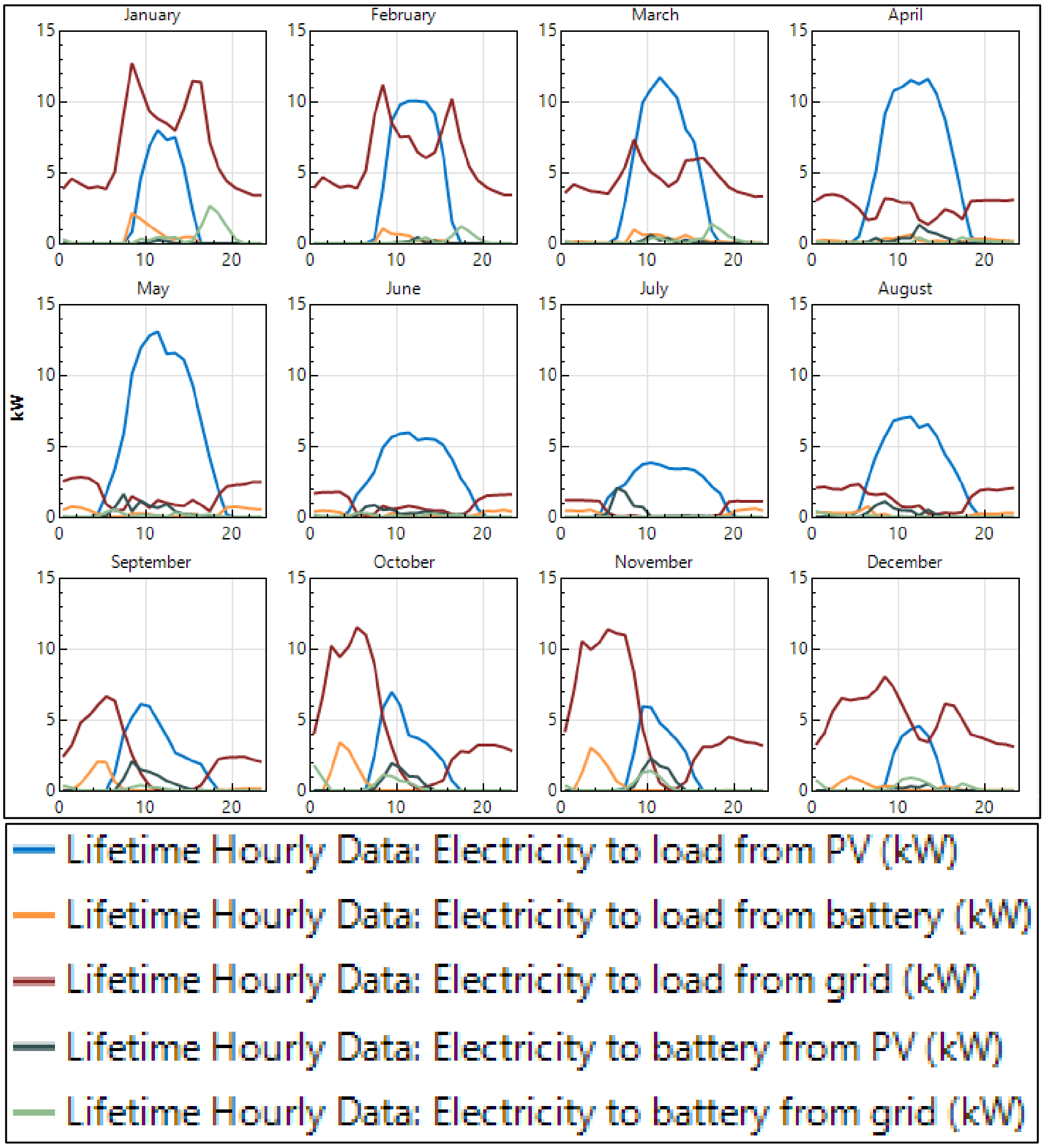

Figure 6.11: Lifetime Electricity Hourly Data for PV and Storage with Strategy 1.4

However, under Strategy 1.4 battery storage was not economically viable and showed negative NPV because the battery storage contribution to building load was particularly during the off-peak prices.

6.4.7 Financial Analysis of All Four Strategies

Table 6.18 and Table 6.19 summarise results of financial assessment of all the above strategies.

As Table 6.18 indicates, combining of solar PV with electricity storage in non-domestic buildings under strategy (1.1, 1.2 and 1.3) is more financially viable and has a shorter payback period compared to the Solar PV system without storage. However, under strategy 4 battery storage was not economically viable and showed negative NPV.

Table 6.18: Scenario 1A; Financial Metric of Integrating of Solar PV (56 kW) With Electricity Storage (42 kWh) with all Examined Strategies

Component	Value for Strategy 1.1	Value for Strategy 1.2	Value for Strategy 1.3	Value for Strategy 1.4	Value for Solar PV without Storage
Annual Energy Yield (Year 1)	56, 644 kWh	56, 644 kWh	56, 644 kWh	56, 644 kWh	56, 644 kWh
Capacity Factor (Year 1)	11%	11%	11%	11%	11%
Performance Ratio [3](Year 1)	0.84	0.84	0.84	0.84	0.84
Battery Efficiency (Incl. Converter + Ancillary)	78.30%	78.30%	78.30%	78.30%	-----------
LCOE	0.25 £/ kWh	0. 23 £/ kWh	0. 24 £/ kWh	0.29 £/ kWh	0.14 £/ kWh
Electricity Bill Without System (Year 1)	£30,297	£30,297	£30,297	£30,297	£30,297
Electricity Bill With System (Year 1)	**£14,502**	**£2,911**	**£4,749**	**£23,373**	**£24,373**
Net Savings With System (Year 1)	**£15,794.25**	**£27,386.25**	**£25,548**	**£6,924**	**£5,924**
NPV	**£72,423**	**£159,521**	**£211,055**	**£-5,055**	**£3,856**
Payback Period	**7.3 years**	**4.5 years**	**4.8 years**	**17 years**	**14.2 years**
Capital Cost	£131,92	£131,92	£131,92	£131,92	£108,705

The system with Strategies 1.2 and 1.3 are more economically viable than the system with Strategy 1.1. However, as Table 6.18 shows, the most attractive business case for installation of PV and behind meter storage in non-domestic buildings would be a system with a battery schedule similar to Strategy 1.2 when battery charge from the grid for 4 hours between Nov and Feb during the off-peak price. Under strategy 1.2 the electricity bill decreases dramatically as a result, it would have a shorter payback

[3] Performance ratio can be calculated using: (sun hours × area × efficiency)

period. However, the business case is similar to Strategy 1.3 in which the battery only charges from the PV and would result in higher NPV. This can be justified with 4% per year increases in electricity price over a lifetime of the project.

As 6.19 shows, with 70 kW as with 56 kW solar PV, the system with Strategies 1.2 and 1.3 is more economically viable compared to the system with Strategy 1.1. However, with 70 kW system the payback period slightly increased but still, the business case would be financially viable.

Table 6.19: Scenario 1B; Financial Metric of Integrating of 70 kW Solar PV with Electricity Storage with Electricity Storage (42 kWh) and with all Examined Strategies

Component	Value for Strategy 1.1	Value for Strategy 1.2	Value for Strategy 1.3	Value for Strategy 1.4	Value for Solar PV without Storage
Annual Energy Yield (Year 1)	68,249 kWh	68,249 kWh	68,249 kWh	68,249 kWh	68,249 kWh
Capacity Factor (Year 1)	11.30%	11.30%	11.30%	11.30%	11.30%
Performance Ratio (Year 1)	0.84	0.84	0.84	0.84	0.84
Battery Efficiency (Converter + Ancillary)	78.30%	78.30%	78.30%	78.30%	----
LCOE	0.33 £/kWh	0.31 £/kWh	0.32 £/kWh	0.36 £/kWh	0.18 £/kWh
Electricity Bill Without System (Year 1)	£30,297	£30,297	£30,297	£30,297	£30,297
Electricity Bill With System (Year 1)	**£12,635**	**£2,221**	**£4,104**	**£22,300**	**£23,737**
Net Savings With System (Year 1)	**£17,662**	**£28,076**	**£26,207**	**£9,997**	**£6560**
NPV	**£71,846**	**£173,361**	**£200,974**	**£-10,974**	**£-4,382**
Payback Period	**7.7 years**	**5.1 years**	**5.5 years**	**17 years**	**16 years**
Capital Cost	£154,975	£154,975	£154,975	£154,975	£131,902

As Table 6.19 indicates, the system with Strategy 1.4 same as the system without storage is not viable in the post-subsidy condition.

In summary, all above strategies have investigated the feasibility of co-locating solar PV system with the behind meter storage with different battery operating modes and indicated that under current economic conditions, the case for battery storage becomes more economically attractive and viable if it is programmed to avoid DUoS and TNoUS charges.

6.4.8 Sensitivity Analysis - Scenario 1

A series of sensitivity analyses were undertaken to validate the models developed in scenario 1. The results of this analysis indicated that the developed models in scenario 1 are sensitives to different parameters including electricity price escalation rate, inflation rate, discounted rate and changes in building electricity demand.

A different range of discount rates (4% to 6%) and an electricity price escalation rate of (3% to 5%) and inflation rates of (2% to 4%) have been run for all the above battery storage strategies. Results indicated that changes in the overall payback period are insignificant. For example, if the electricity costs go up to 5% over the lifetime of the project, inflation increases by 4% and the project should have a real discount rate of 6%, the payback period decreases from 7.3 years to 6.9 years (APPENDIX G).

These analyses also indicated that the highest NPV can be achieved for all three strategies when electricity cost escalation, real discount and inflation rates are 5%, 4% and 2%, respectively. For example, providing these rates, the NPV of scenario 1A has increased by 19.74% (from £72,423 to £86,719.50).

Sensitivity analyses were also run for all three strategies of both scenarios (1A and 1B) by increasing demand by 15% and decreasing demand by 15%. The results indicate changes in the overall payback period and NPV of the system with 56 kW and 70 kW solar PV (scenario 1A) (See APPENDIX G). For example, using a 70 kW solar PV (named as scenario 1B) under strategy 1.3, a 15% decrease in the building demand shows 12.5% decrease in NPV (from £200,947 to £178,461) along with an increase in payback period of almost 1 year (from 5.4 years to 6.2 years). However, if the building demand increases by 15%, NPV increases by 25.6% (from £200,947 to £252,486) while payback period decreases by nearly a year (from 5.4 years to 4.5 years).

However, the results indicated that if the building demand goes up more than 15%, the system size should also be increased. And conversely if the building demand decreases by more than 15%, the system size should also be decreased.

6.5 Scenario 2: Integrating Solar PV with Electricity Storage to Provide Peak Shaving and DSR Services

This scenario evaluates the economic feasibility of integrating behind meter electricity storage with solar PV to provide peak shaving as well as delivering balancing services for the grid.

In order to investigate the most promising business case for integrating behind meter electricity storage with solar PV to provide DSR services, different potential revenue streams have been simulated under two different strategies. Table 6.20 outlines a summary of all of these strategies.

Table 6.20: Summary of Scenario 2's Strategies

	Definition	Aim of the Strategy
Scenario 2	**Strategy 2.1**	To investigate the financial feasibility of using the battery to provide Firm Frequency Response and to avoid TNUoS and DUoS charges in the evening.
	Strategy 2..2	To investigate the financial feasibility of using the battery to provide Short Term operating Reserve and to avoid TNUoS and DUoS charges in the evening.

6.5.1 How Individual Non-Domestic Buildings Can Provide DSR Services

This scenario proposes an approach and illustrates how individual non-domestic buildings with the small storage capacity can provide DSR services. This proposed model enables the building owner to benefit from DUoS and TNUoS avoidances; it also generates additional revenues by providing balancing services for National Grid (including non-dynamic FFR and STOR services) (Figure 6.12).

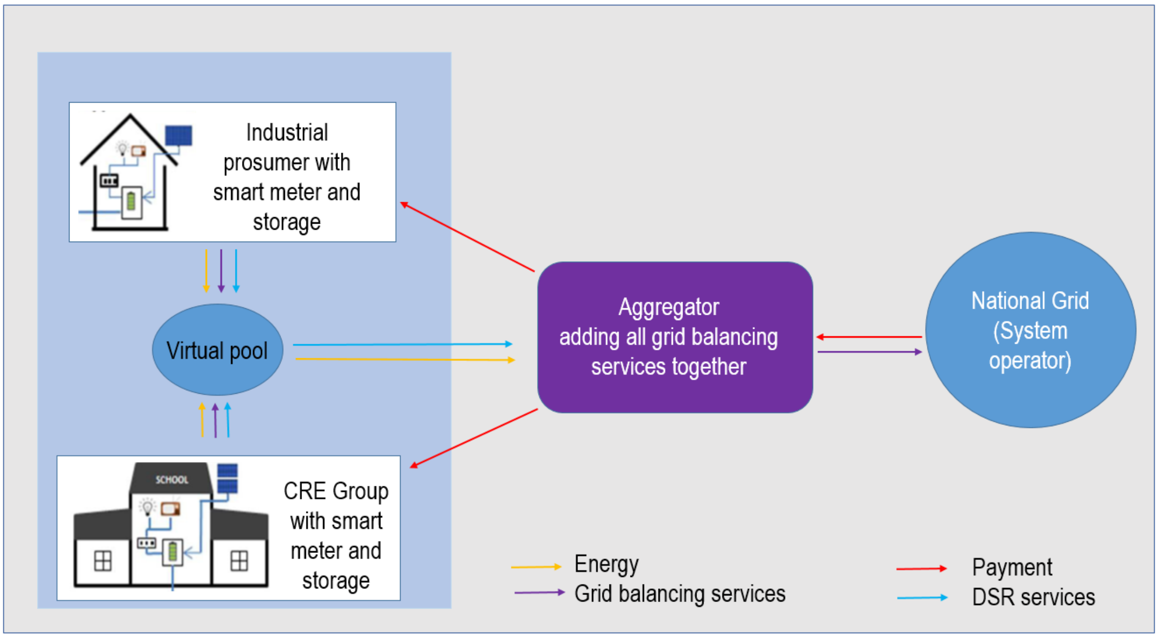

Figure 6.12: Providing DSR and Grid Balancing Services by Individual Non Domestic Buildings

As mentioned in the section 6.3.3 ancillary services can be delivered either in a large capacity or can be aggregated. Therefore, due to the relatively small size of battery storage in non-domestic buildings, this study proposes that a non-domestic building owner wishing to generate revenue by providing balancing service should work in partnership with an Aggregator. An Aggregator works in collaboration with System Operator (SO) including the National Grid to deliver balancing and DSR services.

The majority of Aggregators work based on cloud services that aggregate the energy stored in the systems that the business or households already own such as stationary and mobile storage (e.g electric cars and battery storage). Which, create a virtual energy pool that can be sold to the National grid to help grid stability and reduce its need for power stations (Figure 6.12).

The following sections evaluate how much revenue can be generated for each type of grid service and investigates the financial feasibility of the proposed business model.

6.5.2 System Definition- Scenario 2

Electricity load profile and solar irradiance of this scenario are the same as previous scenario (Figure 6.2 and Figure 6.3), cost assumption and financial parameters of scenario 2 are also the same as scenario 1 (outlined in section 6.4.5) as well as sizes of solar PV system. However, for this scenario, 50 kWh Lithium-Ion battery has been modelled because batteries over 50 kWh are usually able to discharge and charge in response signals from a demand-side manager.

In addition to the size, the potential of provision of DSR services of energy storage can be evaluated by storage performance parameters, including charge and generation capacity, the charge/discharge efficiency, discharge time, the rate of charge and discharge and depth of discharge (DOD) (Telaretti et al., 2016). For example; batteries that provide DSR services should have a response rate (discharge time) within seconds or minutes and should have a long lifespan. Consequently, for this study, a technical specification similar to the Tesla Powerpack (50 kWh) was used for the battery technical speciation (Table 6.21).

Table 6.21: Key System Parameters for Scenario 2 (Battery technical specification complied from (Spirit Energy Limited, 2018)

Component	Parameter	Scenario 2A	Scenario 2B
Site Specification	System Location	London	London
	Building Annual Demand	53,862.69 kWh	53,862.69 kWh
	Building Peak Demand	22.84 kW	22.84 kW
Solar PV System Design	Total Install Capacity	**56 kW**	**70 kW**
	Annual Energy Production	**56,644 kWh**	**68,249 kWh**
	Array Tracking and Orientation	Fixed	Fixed
	Tilt (deg)	35	35
	Azimuth (deg)	180	180
Solar PV Panels	Cell Type	Multi Crystalline Silicon	Multi Crystalline Silicon
	Nominal Efficiency (%)	15.92 %	15.92 %
	Degradation	5%	5%
	Total Number of Modules	**220**	**276**
	Total Module Area	**354.4 m²**	**446.4 m²**
	Solar Lifetime	20 years	20 years
Inverter	Power Rating	**56 kW**	**70 kW**
	Efficiency	98%	98%
	Inverter Lifetime	15 years	15 years
Battery	Battery Installed Capacity	50 kWh	50 kWh
	Lifetime (assumption)	15 years	15 years
	Battery Technology	Tesla Lithium-Ion Powerpack	Tesla Lithium-Ion Powerpack
	Depth of Discharge (DoD)	100%	100%
	Maximum C Rate of Charge (Per/hour)	0.9 = 1 hour	0.9 = 1 hour
	Maximum C Rate of Discharge (Per/hour)	0.5 = 2 hours	0.5 = 2 hours
	Battery Lifetime	15 Years	15 Years
	System Efficiency	87%	87%
	Area Requirements	20.5 m²	20.5 m²
	Dimensions (Width × Height× Depth)	966×2185mm×1321mm	966×2185mm×1321mm
	Continues Power Duration	2 Hours	2 Hours
	AC Voltage	480 VAC 3-phase 400 VAC 3-phase	480 VAC 3-phase 400 VAC 3-phase
	Operating Ambient Temperature	-30 to 50 C^0	-30 to 50 C^0
	Cost (Capex= Installation Costs+ Hardware Costs + Technology Cost)	£529 (£/kWh)	£529 (£/kWh)

6.5.3 Financial Analysis and Evaluating of DSR Revenues

In order to evaluate how much revenue can be generated for each type of DSR service, the amount of electricity which is available for each hourly interval and the rate of charge of each DSR services should be calculated (Gillich et al., 2017).

Each DSR service uses a slightly different methodology for revenue calculation but according to Gillich et al. (2017) all of these DSR revenues can mainly be calculated using equation 6.6:

$$DSR\ Revenue(£) =$$

$$Electricity\ available(kWh) \times Rate\ of\ DSR\ services(\frac{£}{kWh}) \tag{6.6}$$

The potential DSR revenue for each hour is then calculated throughout the year. In order to do this calculation, the model needs the building electricity load throughout the year. The following sections give a detailed overview for each DSR revenue streams (including FFR, STOR) and network charge avoidances.

6.5.3.1 Strategy 2.1: Providing Firm Frequency Response and Peak Shaving Services in Non-domestic Building

The minimum requirement for FFR service is 10 MW which can come from a single unit or be aggregated from smaller loads (Figure 6.14) (National Grid, 2017). When the grid frequency falls below 49.7 Hz, a low-frequency event is caused, which requires a reduction in electricity demand to stabilise the grid imbalance. Conversely, when the grid frequency increases above 50.3 Hz, a high-frequency event is caused, and an increase in demand is required to stabilise the grid frequency (Gillich et al., 2017).

The FFR services can be classified into two groups, Non-dynamic and Dynamic response.

Dynamic frequency response should continuously manage second by second grid frequency imbalances. Non-dynamic frequency response operation is based on frequency deviation which is specified in the tendering agreement, and no response is needed within the operating range (National Grid, 2017).

Dynamic and non-dynamic services can be further classified based on response duration into, primary and secondary (Figure 6.13).

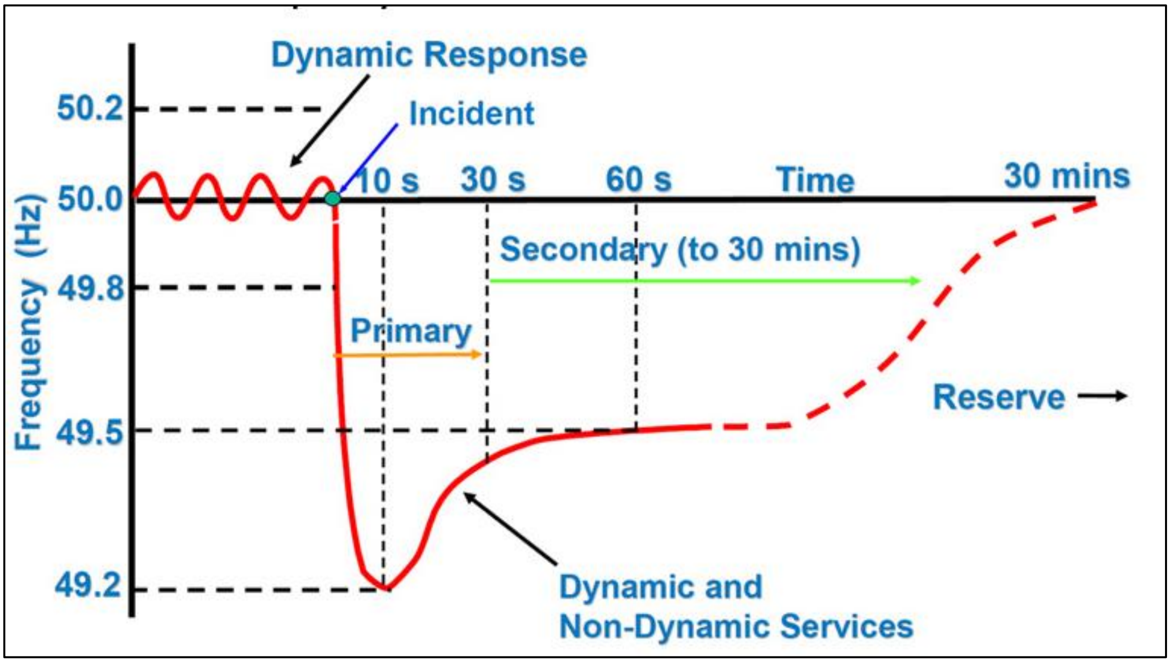

Figure 6.13 : Firm Frequency Response (Saleh et al., 2018)

For primary FFR, a response is needed within 2 seconds and with a full response by 10 seconds, while the secondary response is necessary with 30 seconds (National Grid, 2017). The secondary response is the only non-dynamic response which is procured in the current UK market (National Grid, 2017).

For this scenario, if the battery charging and discharging strategy allows, the battery storage will be fully loaded to provide low non-dynamic FFR. This means that the non-domestic building with lithium-ion battery storage will be contracted for a secondary low non-dynamic FFR to provide demand reduction within 30 seconds of an event and it can be continued for 30 minutes.

6.5.3.2 Battery Charging Strategy for Providing FFR

For this scenario, the system was programmed to meet the building electricity load from the solar PV before charging the battery. The battery storage was programmed with the maximum state of charge of 90%, the minimum state of charge of 10% and the duration of 2 hours to be at the maximum power.

For providing FFR service, the battery system was programmed based on the assumption that the FFR event will potentially happen 20 times throughout the year (2 times every month in Winter, Autumn and Spring and 2 times in the entire Summer at 7:00). Table 6.22 indicates charging and discharging strategy for FFR services.

Table 6.22: Battery Charging and Discharging Schedule for Providing FFR Services and Providing FFR Services & Peak Shaving (Strategy 2.1)

Charge/Discharge Schedule	Charge/Discharge Time for only FFR	Charge/Discharge Schedule for only FFR	Charge/Discharge Schedule for FFR & Peak Shaving	Charge/Discharge Schedule for FFR & Peak Shaving
Nov-Feb Weekdays	24:00 – 3:00	Charge from Grid	24:00 – 3:00	Charge from Grid
Jan-Dec Weekdays	10:00- 16:00	Charge from Solar PV	7:00 – 16:00	Charge from Solar PV
Jan-Dec Weekdays (FFR)	17:00 - 18:00	Discharge 80% each hour	17:00- 18:00	Discharge 75% each hour
Jan -Dec Weekdays (Peak Shaving)	-------------	-------------------	18:00-19:00	Discharge 10% each hour
Jan -Dec Weekends	7:00 – 16:00	Charge from Solar PV	7:00 – 16:00	Charge from Solar PV

Figure 6.14 illustrates the typical example of delivering of FFR in October. During the FFR event at 17:00 the building goes off-grid (red line) and the battery storage discharges to provide electricity for the building (orange line) (Figure 6.14).

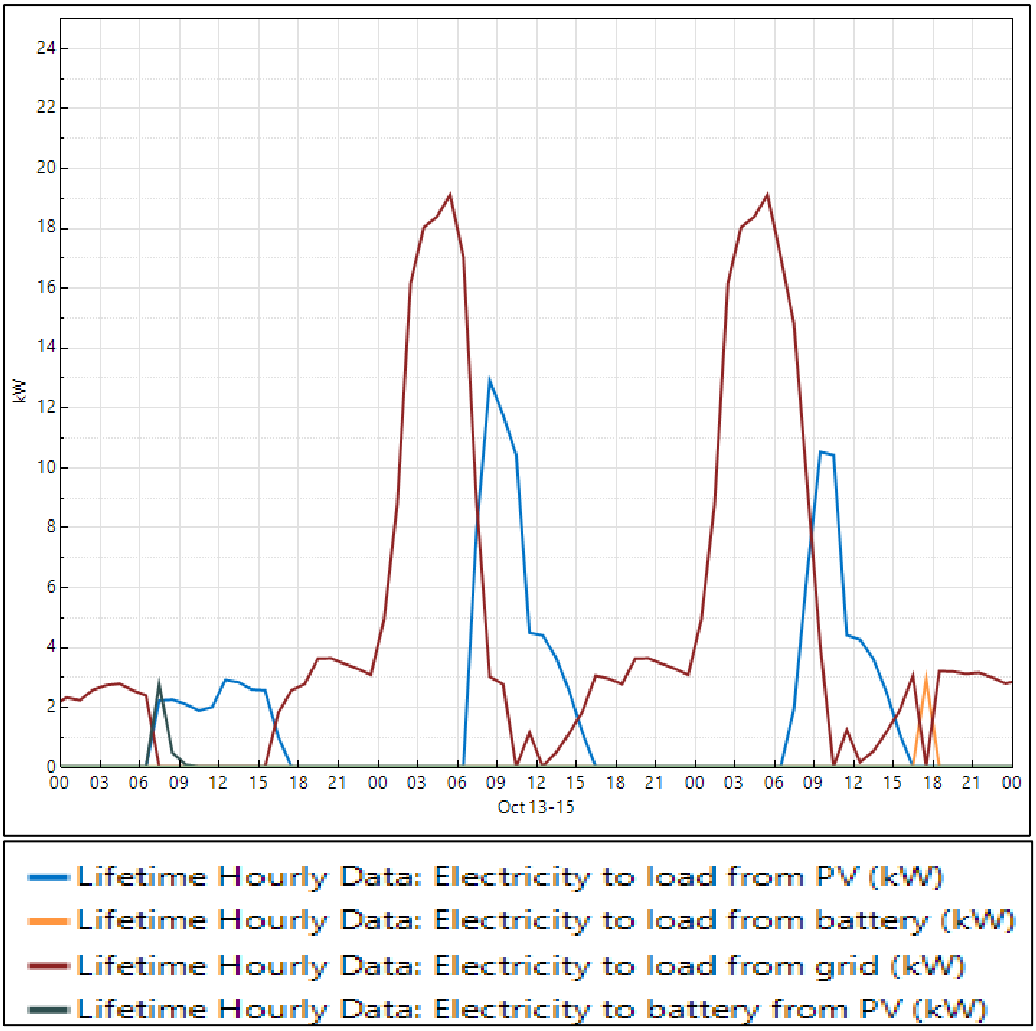

Figure 6.14 Electricity Load profile during Delivery of only FFR Service, Strategy 2, 1

6.5.3.3 Financial Analysis of Providing FFR Services

This service is likely to be needed at any time between 7:00 to 23:00. For this scenario, a maximum duration of 4 hours has been considered for both availability and utilisation window.

The rate of aggregation can vary dependent upon who will take the risk and cover the cost of penalties if the service provider was unable to provide the contracted load. In this study, it has been assumed that Aggregator takes the risk; therefore, we modelled 20% fees for an Aggregator. This fee covers communication and monitoring technologies and, the cost of penalties (Table 6.23).

Table 6.23: Revenue from Delivering FFR Services through an Aggregator for Year 1

Scenario Definition	Number of Event per Year	FFR Availability Window	Available Power	Utilisation Hours	Aggregator Fees	FFR Rate (£/MWh/h)	Revenues (£)
Scenario 2	20	7:00-23:00	50 kW	80	20%	£6.5	£20.8

The revenue stream from only FFR without saving on the bill is minor especially for non-Dynamic services, consequently, providing FFR services is not very economically attractive on its own and would result in negative NPV (Table 6.24). Notably, for aggregated load, when the service provider must also pay Aggregator fees. Additionally, the contract duration for this service is between 6 to 23 months and therefore short.

6.5.3.4 Combining FFR and Peak Shaving

There is potential to utilise both FFR and peak shaving in one day, either FFR happens at the same time or at any time during the red band zone and Triad.

However, in this study, the models are based on FFR events happening in the red band zone and Triad period (See scenario 2A and 2B in Table 6.24). Therefore, under this model, the contracted non-domestic building can benefit from peak shaving and a low non-dynamic FFR at the same time. Because, when the service provider receives the signal to provide steady demand reduction by going off grid and use the battery to meet building loads; they can get paid for contracting with an Aggregator for providing

FFR and also reduce costs on their electricity bills by not using the network system at the same time.

Table 6.24: Scenario 2; Financial Metric of Integrating of PV with Battery to Provide FFR Services and Peak Shaving

Component	Scenario 2A (56 kW PV), FFR and Peak Shaving	Scenario 2A (56 kW PV), with only FFR	Scenario 2B (70 kW PV) FFR and Peak Shaving	Scenario 2B (70 kW PV) with only FFR
Annual Energy Yield (Year 1)	56,6444 kWh	56,6444 kWh	68,249 kWh	68,249 kWh
Capacity Factor (Year 1)	11%	11%	11.30%	11.30%
Performance Ratio (Year 1)	0.84	0.84	0.84	0.84
Battery Efficiency (Incl. Converter + Ancillary)	80.18 %	80.18 %	80.18%	80.18%
LCOE	**0.21 £/kWh**	**0.24 £/kWh**	**0.22 £/kWh**	**0.25 £/kWh**
Electricity Bill Without System (Year 1)	£30,276	£30,276	£30,276	£30,276
Electricity Bill With System (Year 1)	**£4,779**	**£24,916**	**£5,586**	**£23,938**
Net Savings With System (Year 1)	**£ 25,517**	**£5,360**	**£24,711**	**£6,933**
NPV	**£243,192**	**£-20,988**	**£184,656**	**£- 11,977**
Payback period	**4.7 years**	**14 years**	**5.8 years**	**15,90 years**
Capital cost	£136,203	£136,203	£159,544	£159,544

As Table 6.24 indicates, under strategy 2.1 the highest NPV can be achieved from Scenario 2A which was a smaller solar PV system and was able to utilise both peak shaving and providing FFR services.

This sub-scenario emphasises the economic impact of peak shaving on the viability of behind meter storage in non-domestic buildings and indicates that if the system cannot provide peak shaving, it won't be economically viable by only delivering FFR services.

6.5.3.5 Strategy 2.2: Providing Short Term Operating Reserve (STOR) and Peak Shaving Services in Non-domestic Building

The STOR service is considered as the most accessible service to new entrants to the DSR market, with minimum 3 MW load capacity, which can be aggregated or deliver as single load capacity and up to 20 minutes of response rate (Eddie Proffitt, 2017).

This sub scenario considers the system where the battery storage is programmed to maximise revenue from the STOR services contract. The following sections investigate the financial impact of the STOR on uptake of behind meter battery storage.

6.5.3.6 Battery Charging Schedule for STOR Services

In scenario 2 for providing STOR services the manual controller was programmed to meet the building electricity load before charging the battery. It is predicted that STOR services will be required at least 3 times a week. Table 6.25 indicates charging and discharging schedule for STOR services.

Table 6.25: Battery Charging and Discharging Schedule for Providing STOR Services

Charge/Discharge Schedule	Charge/Discharge Time	Charge/Discharge Schedule
Nov-March Weekdays	24:00 - 3:00	Charge from grid
Jan -Dec Weekdays	8:00- 16:00	Charge from Solar PV
Jan-Dec Weekdays	17:00- 19:00	Discharge 45% each hour
Jan-Dec Weekends	7:00 - 19:00	Charge from PV

6.5.3.7 Financial Analysis of Providing STOR Services

The availability window refers to particular times of the day when the STOR services are more likely to be needed; therefore, the storage provider must be able to deliver service during these windows (Figure 6.15). However, STOR might need outside of availability window (Eddie Proffitt, 2017). For this scenario, only evening availability window (window 2) has been evaluated. In this scenario, the storage battery can be charged with electricity generated by the solar PV system during the day, and will be discharged in the evening in response to a signal from the Aggregator (or National Grid) to provide demand reduction, the STOR event can last for 2 hours.

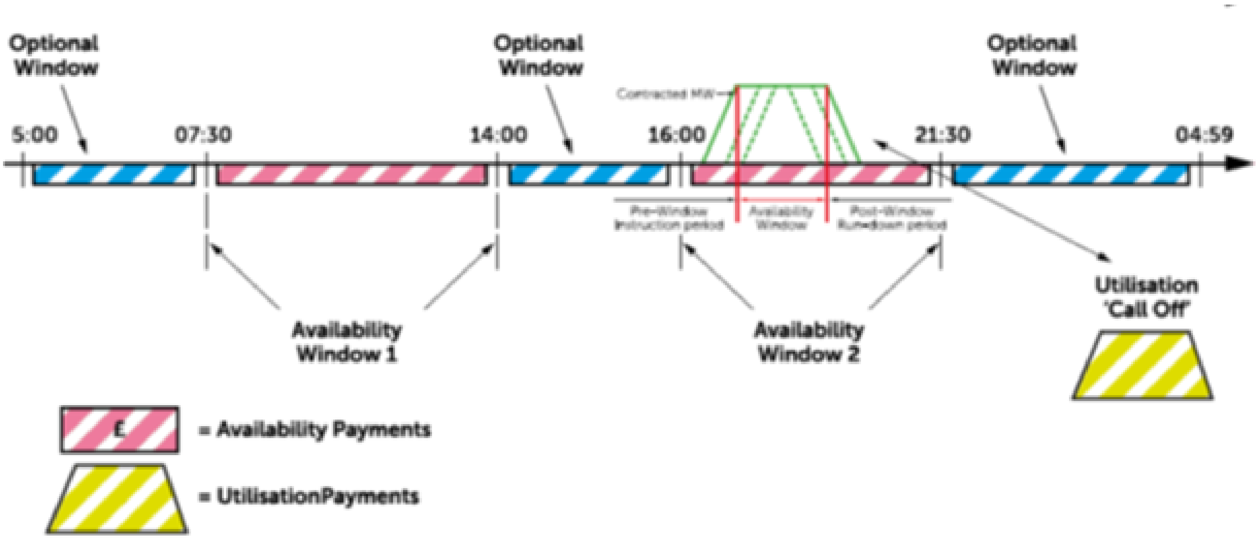

Figure 6.15: Availability and Utilisation Windows for Providing STOR Services through 24 Hours

The modelling shows that the storage provider can generate revenue from the availability window as well as the utilisation window which is necessary to deliver a steady demand reduction.

As Figure 6.16 which is a typical example of delivering of STOR in January shows, the battery storage was charged from the grid during off-peak prices (24:00 to 3:00) in winter (green line) to be fully loaded. Between 17:00 and 19:00 when the STOR event happens the building goes off-grid (red line) and battery supplies electricity for the building demands; consequently the STOR provider can also deliver a steady demand reduction (orange line).

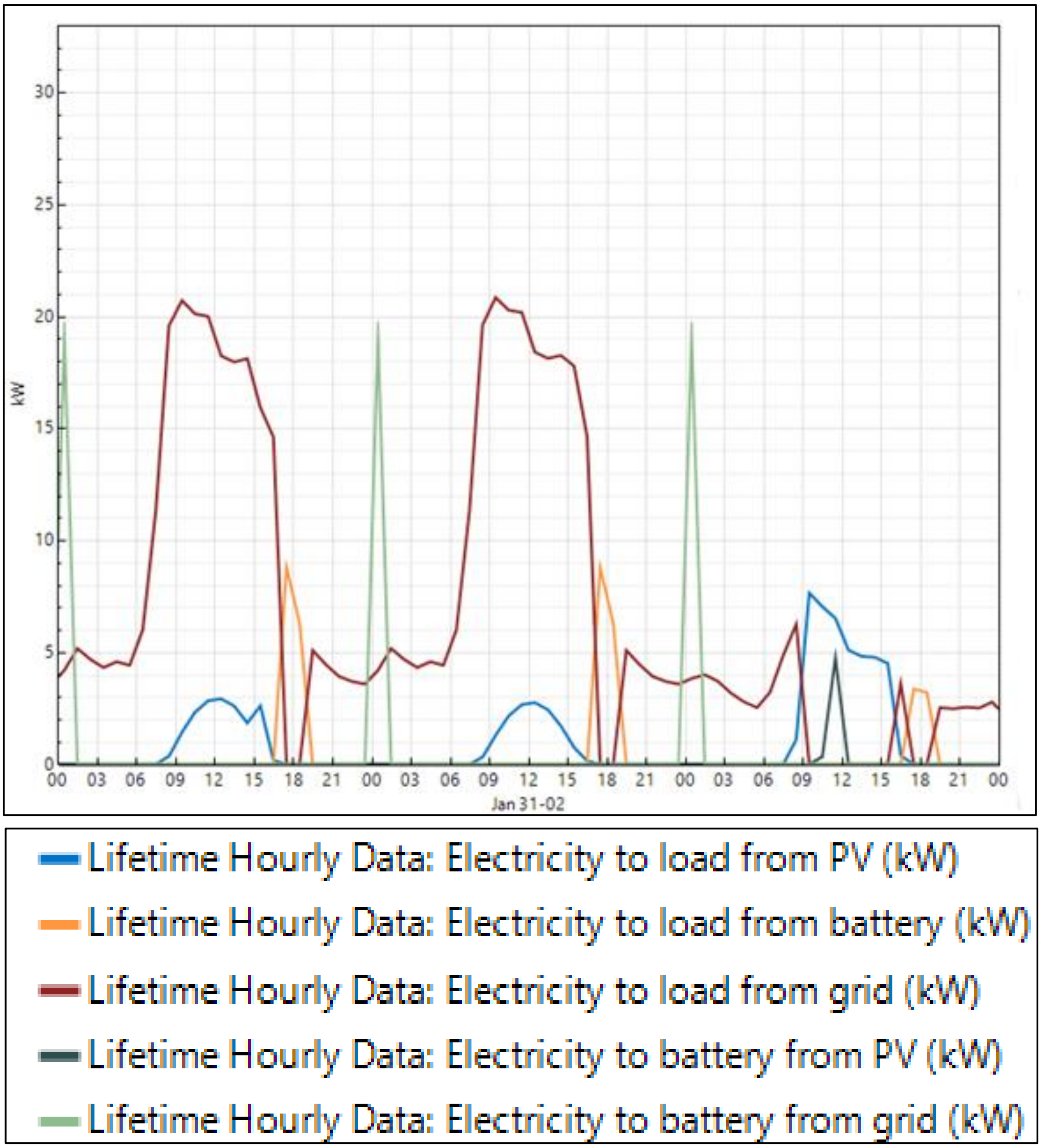

Figure 6.16: Electricity Load profile during Delivering STOR Service, Strategy 2.2

As outlined in Table 6.26, under this model the storage provider can generate £1,462 annually for both availability and utilisation payments, (after paying Aggregator fees).

Table 6.26: Revenue from Providing STOR Services (based on Gillich et al., 2017)

STOR Period/ Season	Available Power (kW)	Hours	Aggregator Fee	STOR (£/MWh/h)	Revenue
March-Oct (Availability Window 16:00-22:00)	50 kW	576	20%	£2.69	£62
March-Oct (Utilisation Window 17:00-19:00)	50 kW	192	20%	£91.32	£701
Nov-Feb (Availability Window 16:00-22:00)	50 kW	288	20%	£6.31	£73
Nov-Feb (Utilisation Window 17:00-19:00)	50 kW	96	20%	£162.92	£626
Total Gross Revenue (Year 1)					**£1,462**

6.5.3.8 Combining STOR and Peak Shaving

The previous section has indicated that providing DSR services can create revenue for storage providers/owners. Because the predicted period of the STOR availability windows and DUoS and TNUoS (Red band Price and Triad) charges almost occur at the same time, potentially the non-domestic electricity storage provider can benefit from both services. This means when the STOR service provider receives the signal to provide steady demand reduction by going off grid and use the battery to meet building loads, they can be both paid by contract for delivering STOR and also save a significant amount money on their electricity bills by not using the network system at the same time.

Table 6.27 illustrates all the financial metrics of the scenario 2 systems with both STOR services and avoiding network charges and the system with only network charge avoidance. The contract duration for STOR services is flexible, for proposed business model considered the STOR revenue for 15 years.

Table 6.27: Scenario 2 Financial Metric; of Integrating of PV with Battery to Provide STOR Services and Peak Shaving

Component	Scenario 2A (56 kW PV), with Only Peak Shaving	Scenario 2A (56 kW PV), with STOR and Peak Shaving	Scenario 2B (70 kW PV) with Only Peak Shaving	Scenario 2B (70 kW PV) with STOR and Peak shaving
Annual Energy Yield (Year 1)	56,644 kWh	56,644 kWh	68,249 kWh	68,249 kWh
Capacity Factor (Year 1)	11%	11%	11.30%	11.30%
Performance Ratio (Year 1)	0.84	0.84	0.84	0.84
Battery Efficiency (Incl. Converter + Ancillary)	79.30%	79.30%	79.30%	79.30%
LCOE	0.25 £/kWh	£0.22 £/kWh	0.25 £/ kWh	0.23 £/kWh
Electricity Bill without System (Year 1)	£30,297	£30,297	£30,297	£30,297
Electricity Bill with System (Year 1)	**£4,776.75**	**£4,776.75**	**£2,373**	**£2,373**
Net Savings with System (Year 1)	**£25,519**	**£26,016**	**£27,924**	**£27,924**
NPV	**£243,171**	**£256,343**	**£229,425**	**£241,990**
Payback Period	**4.7 years**	**4.4 years**	**5.2 years**	**4.9 years**
Capital Cost	£136,203	£136,203	£159,544.25	£159,544.25

The highest NPV can be achieved from the Scenario 2B; therefore the system was programmed to provide STOR services and avoid paying network charges by using battery storage at peak price times.

Since the requirement for the STOR utilisation window is predicted to occur at the same time as the peak prices, the service provider can benefit from both sides. Providing STOR services slightly increases NPV value of the system and reduces the payback period. However, this scenario shows that the main advantage of up taking the behind meter battery storage comes predominantly from Peak shaving (Network charge avoidance) rather than providing DSR services.

6.5.4 Combining All Three Services (Peak shaving, STOR and FFR)

The above sections have outlined that how each DSR service can generate revenue for the storage provider and highlighted the potential of utilising more than one DSR service during the day. As has been highlighted network charge avoidance by peak shaving generates the highest revenue out of three revenue services (Table 6.28). Therefore, if a storage provider cannot utilise all services together priority should be given to network charge avoidance followed by STOR and finally FFR.

Table 6.28: Gross Revenue from Providing DSR and Peak Shaving

Services	Revenue (£) for Year 1
Peak Shaving	£10,691
STOR	£1,462
FFR	£20
Total Gross Revenue (Year 1)	**£12,173**

6.5.5 Sensitivity Analysis - Scenario 2

Sensitivity analysis results show that the models developed in scenario 2 are sensitive to different parameters including electricity price escalation rates, inflation rates, discounted rates, changes in the payment rates of STOR and FFR and changes in building electricity demand.

A different range of discount rates (4% to 6%) and an electricity price escalation rate of (3% to 5%) and inflation rates of (2% to 4%) have been run for all the above battery storage strategies. The results same as scenario 1 indicate that there are insignificant changes in the overall payback period.

A series of sensitivity analyses with increases of between 15% and 25% in the payment rates of DSR services (including STOR and FFR) have also been run.

The sensitivity analysis with different range of FFR revenue indicated insignificant changes in the overall payback periods and NPV. Similarly, the same escalation rate has been simulated for STOR payment which shows a minor increase in the NPV and payback periods. For example, if the STOR payment increases by 25% for scenario 2B (with 70 kW PV and 50 kWh storage system) the payback period decreases by one month (4.9 years to 4.8 years) and NPV increases by 1.2% (from £241,990 to £244,984).

Sensitivity analyses were also run for all two strategies for both scenarios (2A and 2B) with a 15 % higher and 15% lower electricity demand. Results indicate on average that if the building demand increases up to 15%, the payback period decreases by around four months for all three strategies. However, if the building demand decreases up to 15%, it would have an insignificant effect on the NPV whilst it will increase the payback period by about a year.

These analyses have shown that the model is replicable for buildings with higher electricity demand. Furthermore, if the building demands increased by up to 15% the system is still able to provide DSR services and meet building loads. However, the results also indicated that if the building demand goes up more than 15%, the system size should also be, increased. And conversely if the building demand decreases by more than 15%, the system size should also be decreased.

6.6 Scenario 3: Developing An Innovative Alternative Business Model For Community-owned Solar Projects

The previous scenarios have shown that investment in combining electricity storage and solar PV system for non-domestic buildings will payback before the end-life of the system and will have a shorter payback period by maximising self-consumption, peak shaving and providing DSR services through an Aggregator. Based on the result of previous scenarios, an alternative business model has been proposed for the UK's community-owned solar projects in this final scenario. After introducing the alternative business model, a series of techno-economic analyses were run under different three economic strategies to create a viable revenue model and to investigate the financial and technical feasibility of the developed model (Table 6.29).

Table 6.29: Summary of Scenario 3's Strategies

	Definition	Aim of the Strategy
Scenario 3	**Strategy 3.1**	To investigate the techno-economic feasibility of providing STOR by CRE groups.
	Strategy 3.2	To investigate the techno-economic feasibility of providing DSR by CRE groups.
	Strategy 3.3	To investigate the techno-economic feasibility of selling electricity to the host building based on TOU PPA.

6.6.1 Introducing an Innovative Alternative Business Model

This section illustrates an innovative alternative business model, 'Sun Community-owned Energy Storage' model that has been developed based on the existing CRE business structure and by using revised Osterwalder and Pigneur (2010) business model Canvas.

The alternative business model optimises the existing model by adding electricity storage. Under this alternative model 'Community-owned Energy Storage', a CRE group lease a roof from a community building such as school or care home to install solar PV and storage. The solar electricity generated provides low-cost electricity for the community venue. Any electricity surplus is stored for use at peak price times. This decreases the grid dependency of the host building.

Under this model, the residents of a host building can buy and use generated electricity under the Time of Use Power Purchase Agreement (TOU PPA) almost throughout the day even when the sun is not shining.

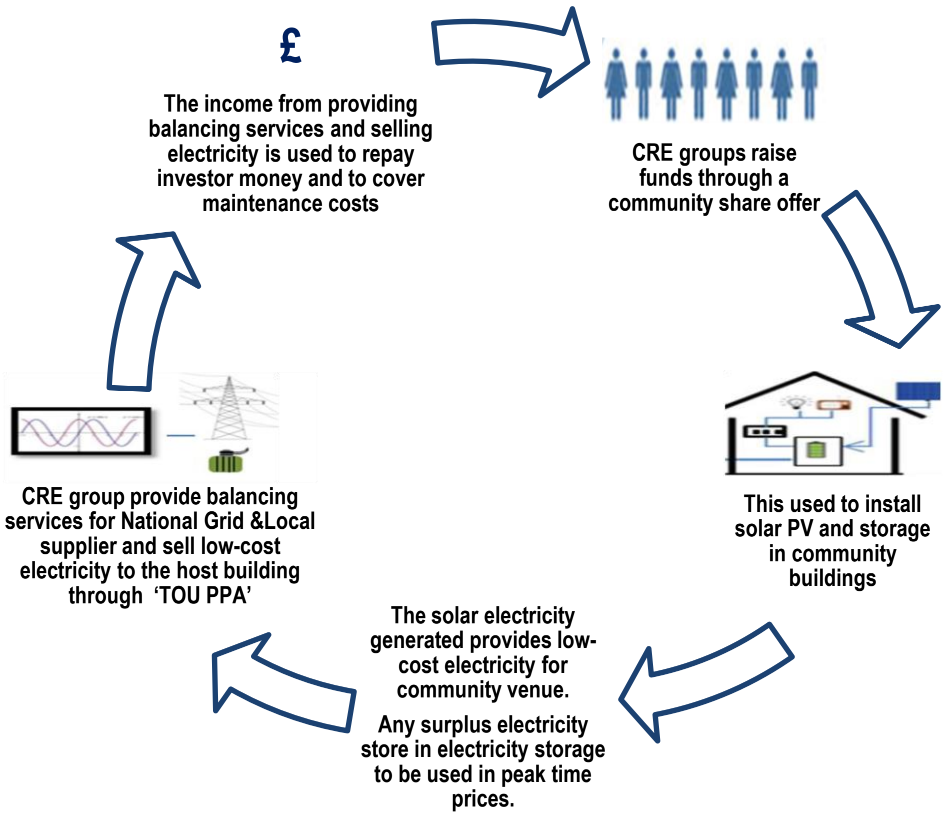

Figure 6.17: 'Community-owned Energy Storage' Business Model Operation

This approach provides an opportunity for the tenant to avoid network charges and offers a significant saving on their electricity bills. CRE groups operate and maintain solar PV and work in partnership with an Aggregator and supplier to provide balancing and DSR services, receiving revenues from providing these services (after paying Aggregator and supplier fees) (Figure 6.17).

6.6.2 Characteristics of 'Community-owned Energy Storage' Model

The four fundamental areas of the Osterwalder and Pigneur (2010) business model Canvas have been applied to develop and characterise 'Community-owned Energy Storage' model (Figure 6.18).

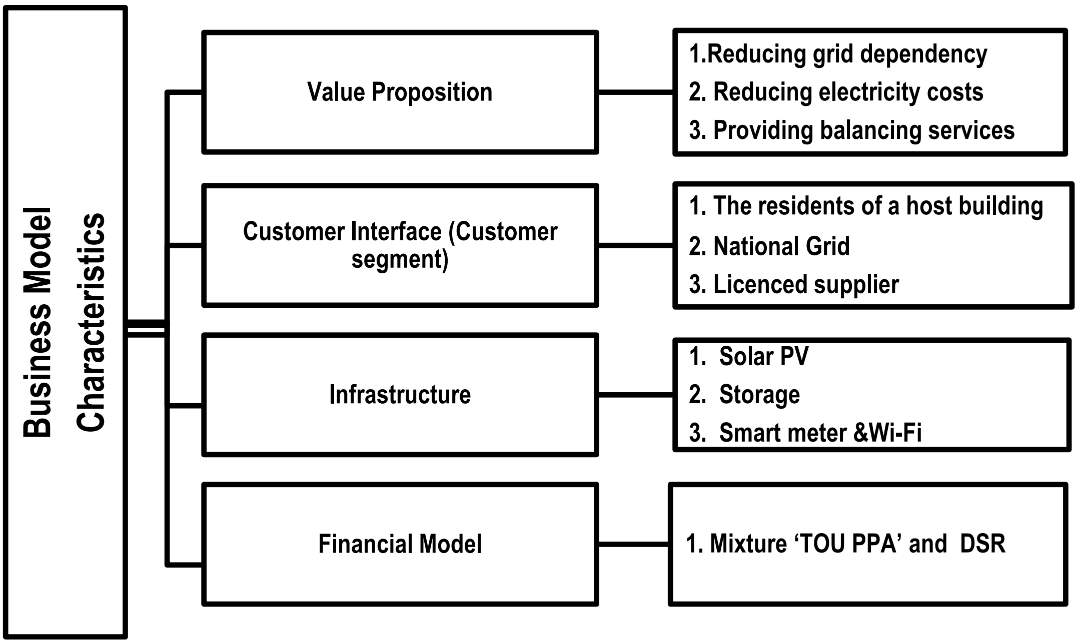

Figure 6.18 Business Model Structure 'Community-owned Energy Storage' for Solar PV Projects Based on (Osterwalder and Pigneur 2010)

The customer segment of this model will be the host building tenant as the CRE group sell generated electricity to them at a lower cost than National grid based on the time of their use. Also under this model CRE group provide balancing services for the National grid and a licensed supplier.

The key infrastructure and resources required for operating 'Community-owned Energy Storage' model are rooftop solar PV, electricity storage, smart meter and Wi-Fi.

However, this alternative business model does require more technical and business expertise including knowledge of operating and developing storage projects and providing demand-side services, unlike existing CRE models which were originally based on a low-risk FIT model. Consequently, this study proposes to CRE groups to work in partnership with an Aggregator and local supplier for developing projects under the alternative business model.

6.6.3 Providing DSR Services under this Alternative Business Model

As in the previous scenario the CRE groups provide service to an individual non-domestic building through an Aggregator.

As Figure 6.19 illustrates under the developed model 'Community-owned Energy Storage', an Aggregator adds together all the energy stored in the storage systems that the business or CRE groups are already owned. The aggregated loads create a virtual energy pool which would be sold to the National grid in the event of STOR or FFR to help grid stability. Consequently, each individual storage provider would receive a payment based on the energy capacity or the demand reduction they provide in response to the signal they receive from the Aggregator at the time of FFR or STOR event (The storage provider would pay fees to Aggregator for their service).

In addition to grid services revenue (STOR and FFR), CRE groups can also provide DSR services for the supplier and be paid (Figure 6.19). Currently, due to changes in industry rules for energy supplier, it is very expensive for a supplier to generate or consume more than they have contracted. Consequently, some suppliers pay customers based on the actual imbalance costs to provide them with DSR services by reducing their electricity demand or shifting to on-site generation or storage (missioncriticalpower, 2016).

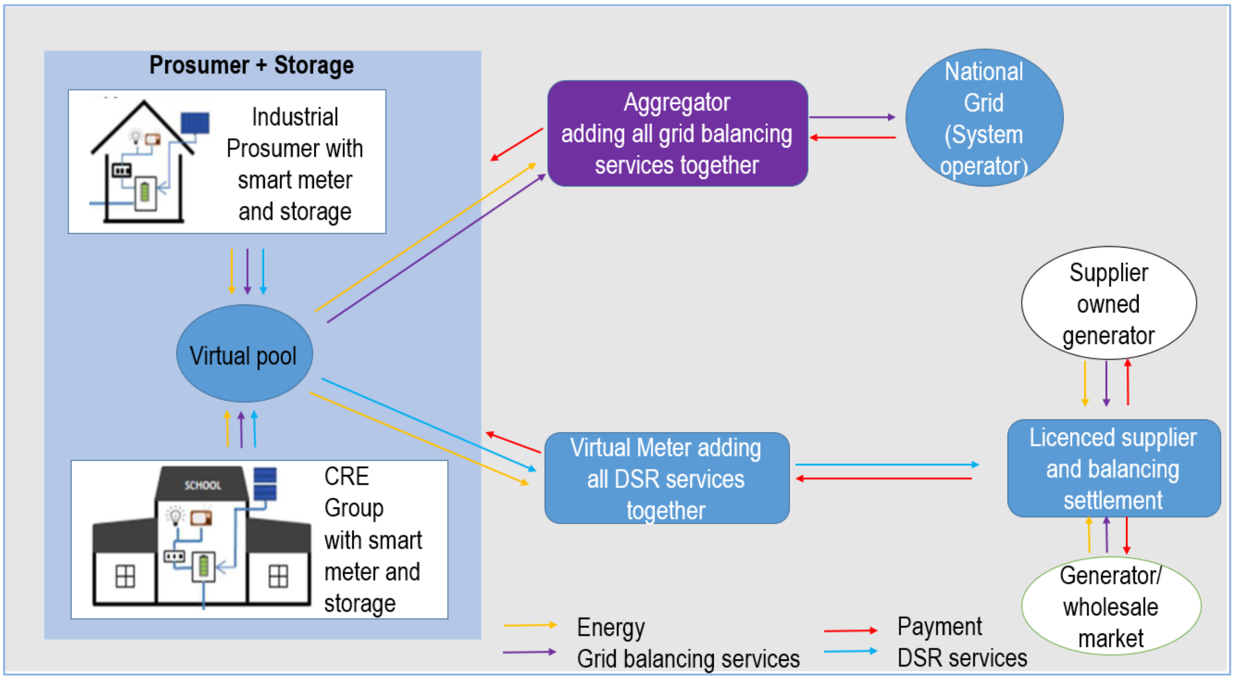

Figure 6.19: Providing DSR Services Under ‘Community-Owned Energy Storage’ Model

Working in partnership with the suppliers that invite DSR participants provides an opportunity for CRE groups to generate another source of income in addition to STOR revenue and increase the viability of community-owned combined solar and storage projects.

The following section investigates the economic feasibility of the proposed business model (‘Community-owned Energy Storage’) and alternative policy approaches.

6.6.4 System Definition - Scenario 3

The electricity load profile and solar irradiance, and all system configurations of this scenario, are the same as the previous scenario. The difference between this scenario and the scenario 2 is the ownership model and the method of raising finance for the project.

In scenario 2 it was assumed that the non-domestic building owner would install solar rooftop PV and the battery storage to reduce their electricity bills. In this scenario, as in the existing CRE business model, a community-led energy organisation leases roofs for 15 years from the community to install rooftop solar PV and storage on the community buildings delivering reduced energy costs and combating fuel poverty within the community.

6.6.4.1 Financial Analysis Parameters and the Cost Assumption

In order to create a viable financial model for the innovative alternative business model in the post-subsidy conditions, the 'Community-owned Energy Storage' model was tested with a different financing model (loan and community share). The results indicated in order to, the 'Community-owned Energy Storage' business model to become financially viable currently, CRE groups should have access to zero interest loans for 50% of the cost of installing solar PV plus storage system and raise the remaining 50% through a community share (equity) offer. This approach would result in higher NPV because under this approach CRE groups only pay interest for half of their capital costs. Therefore, for Scenario 3 it has been assumed that CRE groups have access to zero interest loans for 50% of the cost of installing solar PV plus storage system and would raise the remaining 50% through a community share (equity) offer. Based on the results of the semi-structured interviews a community share offer with a 4.5% return on investment has been modelled for this study.

Table 6.30 outlines the financial parameters that have been used to run a cash flow analysis for this scenario.

Table 6.30: Financial Parameter for Scenario 3

Parameter	Value
Project Lifetime	15
Investment Interest Rate	4.5%
Inflation Rate	2.5%
IRR	4.5%
Loan Term	15 years
Type of Loan	0% Interest (No Interest)

The assumed financial parameters for capital cost in this scenario were the same as the previous scenarios.

6.6.5 Strategy 3.1: Battery Charge and Discharge Schedule for Delivering STOR Services

Due to the third party structure of CRE projects, charging batteries from the grid during the off-peak price period would be challenging and might be impossible for CRE groups, unlike the previous scenarios. Consequently, for this scenario, the battery was programmed to be fully charged from PV before meeting the building electricity demand particularly between November and February when solar energy generation is low.

Figure 6.20 illustrates the typical example of delivering of STOR by CRE groups in March under programmed strategy (Table 6.31). With the programmed strategy CRE groups can deliver a steady demand reduction between 17:00 and 19:00 (utilisation window) by going off-grid for 2 hours (Red line) and using stored electricity to meet the building electricity demands (Blue line). Which enables them to generate £1,553 annually for period of 15 years.

Table 6.31: Battery Charging and Discharging Schedule for Providing STOR Services by CRE Group

Charge/Discharge Schedule	Charge/Discharge Time	Charge/Discharge Schedule
Jan -Dec Weekdays	8:00 -16:00	Charge from PV
Jan-Dec Weekdays during STOR period	17:00 - 19:00	Discharge 45% each hour
Jan-Dec Weekends	7:00 – 19:00	Charge from PV

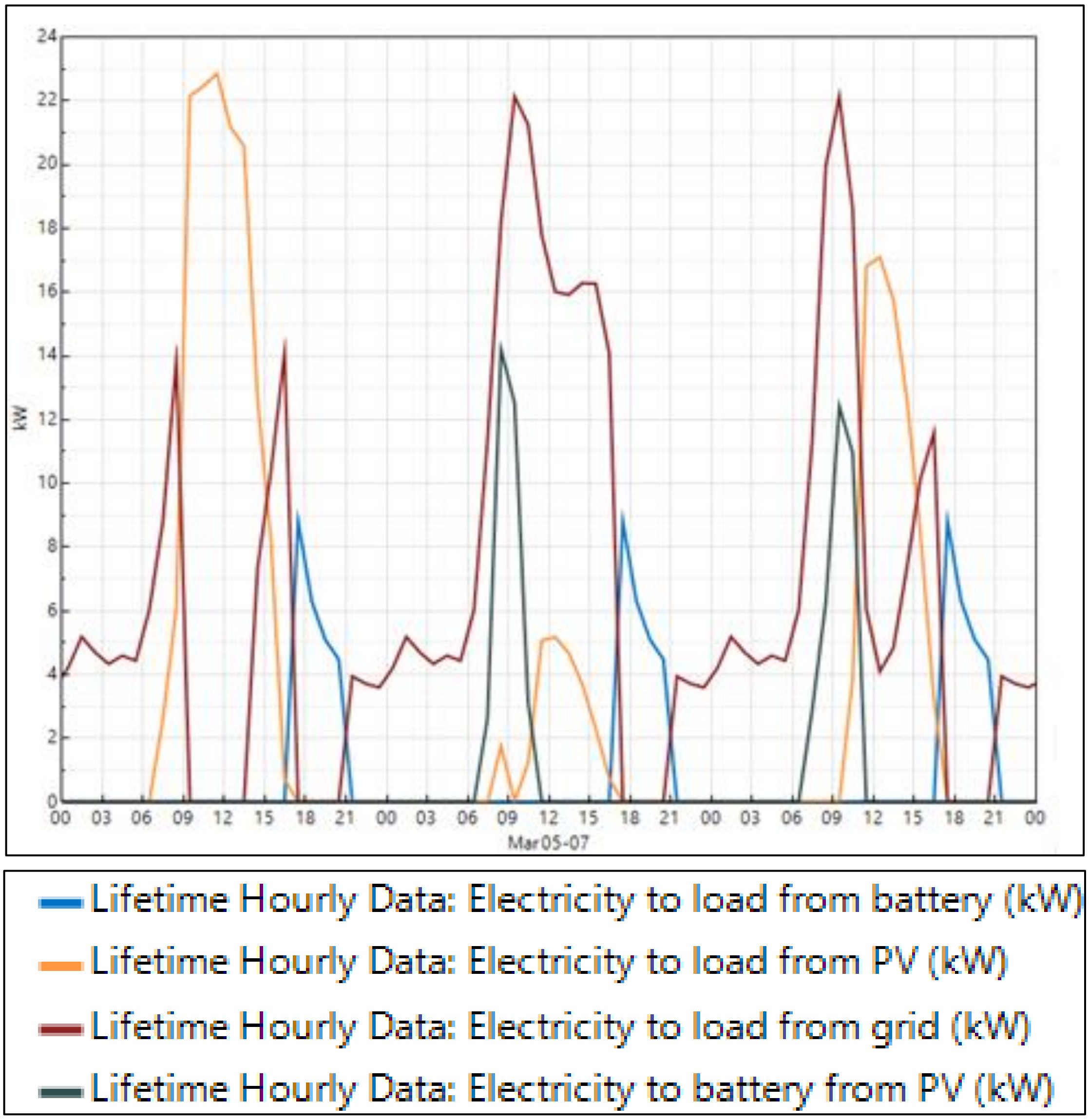

Figure 6.20: Providing STOR Services by CRE Group Strategy 3.1

Also, the battery is programmed to be charged over the weekend without any electricity discharge so that it is fully loaded and able to provide STOR demand reduction during the week throughout the year (Table 6.31).

6.6.5.1 Financial Analysis of Providing STOR Services

The modelling in the previous scenario indicated that, the storage provider can generate revenue from both the STOR availability window and the utilisation window by providing a steady demand reduction.

Table 6.32: Revenue from Providing STOR Services (based on Gillich et al., 2017)

STOR Period or Season	Available Power (kW)	Hours	Aggregator Fee	STOR (£/MWh/h)	Revenue (£)
March-Oct (Availability Window 16:00-22:00)	50 kW	576	15%	£2.69	£66
March-Oct (Utilisation Window 17:00-19:00)	50 kW	192	15%	£91.32	£745.17
Nov-Feb (Availability Window 16:00-22:00)	50 kW	288	15%	£6.31	£77.23
Nov-Feb (Utilisation Window 17:00-19:00)	50 kW	96	15%	£162.92	£664.60
Total STOR Revenue (£) for Year 1					**£1,553**

Considering the social enterprise nature of CRE projects for this scenario a 15% Aggregator fees was modelled (Gillich et al., 2017). The Aggregator fee covers, cost of penalties, communication and monitoring technologies. The CRE groups by providing STOR services can potentially generate £1,553 annually for the period of 15 years (Table 6.32).

6.6.6 Strategy 3.2: Battery Charge and Discharge Schedule for Delivering DSR Services

Due to the third-party ownership structure of CRE projects, they cannot directly benefit from network charge avoidance unlike projects evaluated in the previous scenarios. However, they can potentially provide DSR services to suppliers and generate income.

Under the 'Community-owned Energy Storage' model, the CRE group can provide DSR services for the supplier twice during the day: First in the morning when typically solar generation is very high, and the grid is constrained due to high solar electricity penetration and, second in the evening when electricity demand is very high.

6.6.6.1 Financial Analysis of Providing DSR Services

In order to investigate the financial viability of providing DSR services for a licenced supplier by the CRE group, the electricity storage was programmed to be charged from 11:00 to 14:00 throughout the year from PV and be discharged between 16:00 and 19:00 which is usually the period of peak electricity demand (Table 6.33).

Table 6.33: Battery Charging/Discharging Schedule for Providing DSR Services by CRE Groups under the Alternative Business Model

Charge/Discharge Schedule	Charge/Discharge Time	Charge/Discharge Schedule
Jan-Dec Weekdays	11:00 -14:00	Charge from PV
Jan-Dec Weekdays	16:00 – 19:00	Discharge 22% each hour
Jan -Dec Weekends	7:00- 19:00	Charge from PV
Jan-Dec Weekends	7:00 – 17:00	Charge from PV

Figure 6.21 indicates that the modelling was successful and the tenant of the host building was able to shift demand and deliver a steady demand reduction by utilising generated solar PV. Based on this battery strategy, the battery storage discharged (Orange line) between 16:00 to 19:00 (peak demand period) consequently, the building goes off-grid during the peak demand period (Blue line).

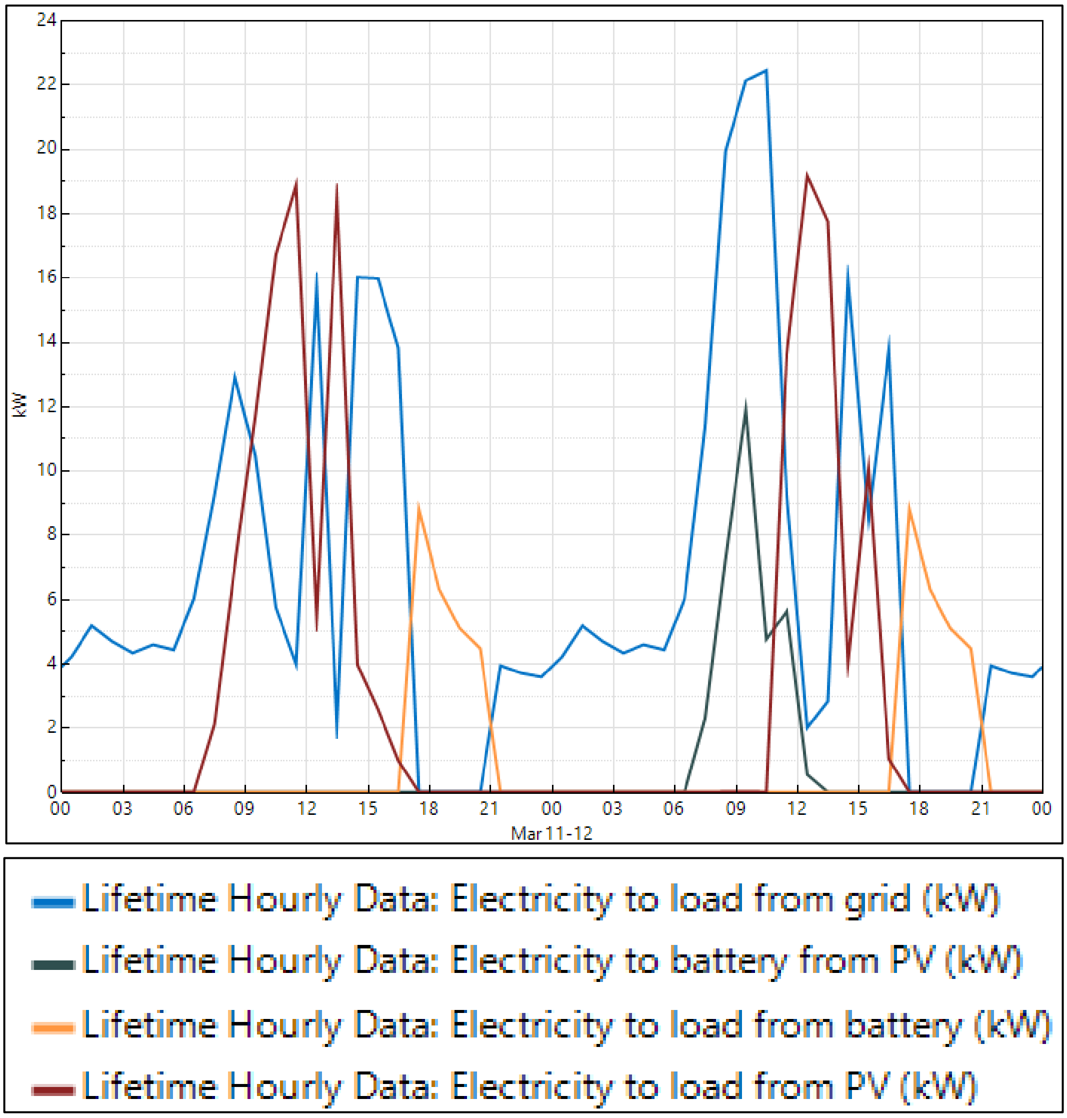

Figure 6.21: Providing DSR Services for Supplier by CRE Groups Strategy 3.2

It is predicted that for providing DSR services, there would be no need of significant behavioural changes by residents of host buildings due to the increased flexibility provided by storage. For example, if the electricity demands are lower than generation surplus of electricity would charge the battery (Figure 6.21 Dark green line) and vice versa, if the demand is higher than electricity generation, storage would supply the building demands.

By providing DSR services the CRE projects will potentially receive a payment from a supplier based on the load they reduced or shifted. In order to identify how much revenue the CRE groups can potentially generate from these services and based on the actual balancing costs, the model includes the CRE group receives £0.10 per kWh for providing DSR services between 11:00 and 14:00, 16:00 and 19:00 each day (Elexon, 2013; missioncriticalpower, 2016).

As Table 6.34 indicates, under the alternative model, the CRE groups can generate £9,282 annually by providing DSR services for a supplier.

Table 6.34: Annual Revenue from Only Providing DSR Services under Alternative Business Model

DSR Services	Available Power (kW)	Hours	Rate (£/kWh)	Supplier Fees	Revenue
All Year (11:00-14:00)	50 kW	1,092	£0.10	15%	£4,641
All Year (16:00-19:00)	50 kW	1,092	£0.10	15%	£4,641
Total DSR Revenues (Year 1)					**£9,282**

6.7 Strategy 3.3: Selling Electricity through the Time of Use Power Purchase Agreement

As, mentioned in CHAPTER 4 prior to the reduction of FIT, selling solar PV generated electricity directly to host buildings through a PPA was one the main sources of revenue for the majority of CRE projects. However, this approach is no longer viable with reduced FIT as a PPA would have to charge as much as the grid or even higher to be financially viable (Section 6.2.4).

Providing grid and DSR services by integrated community-owned solar PV system and electricity storage will decrease the LCOE of the project. However, in order to make community-owned solar projects fully financially viable without any Government incentives, in addition to providing balancing and DSR services, CRE groups also need to directly sell electricity to host buildings and this needs to be advantageous to the tenants.

Therefore the study proposes, that community-owned solar projects should sell electricity to the tenant through a 'TOU PPA'. This means selling electricity at different prices based on the amount of electricity used by host building in different time periods. Under the 'TOU PPA' approach, a host building would buy electricity through the PPA at two different rates based on their time of use and when solar PV and storage are not in operation from the licenced supplier based on TOU tariff.

The 'TOU PPA' approach, enables CRE groups to sell their electricity at a reasonable price whilst in return, providing an opportunity for the host building tenants to avoid network charges (See Scenario 1 and 2) and thus still offer a significant saving on their electricity bills.

A similar example of 'TOU PPA' model was adopted, by the California Public Utilities Commission (CPUC) in 2005 based on time of delivery. Under the CPUC model, renewable energy developers sell electricity to California Utility at different prices based on the different factors including capacity values and delivering electricity in different time and season (Salazar and Johnson, 2006).

Table 6.35: Comparing Proposed PPA Price to a Normal Non-Domestic Electricity Price in London (including DUoS and TNUoS charges)

Period of Use for PPA	TOU for PPA	PPA Price (£/kWh)	National Grid Electricity Price (£/kWh)
Jan-Dec Weekdays	7:00 – 11:00	£0.09	£0.16
Jan-Dec Weekdays	11:00 -14:00	£0.09	£0.19
Jan-Dec Weekdays	14:00 – 16:00	£0.09	£0.16
Nov-Feb Weekdays	17:00 -18:00 (Triad)	£0.13	£54.96
March-Oct Weekdays	16:00-19:00	£0.13	£0.19
Jan- Dec Weekdays	20:00 -23:00	£0.13	£0.16
Jan- Dec Weekdays	24:00 - 6:00	£0.13	£0.15
Jan - Dec Weekends	7:00 -17:00	£0.09	£0.15
Jan - Dec Weekends	17:00 – 23:00	£0.13	£0.15

Table 6.35 presents the proposed 'TOU PPA' rates. Under 'Community-owned Energy Storage' model and 'TOU PPA' approach community-owned solar projects can supply electricity to the host building at a lower price than the buying electricity from the grid and still be financially viable without any incentives.

6.7.1 Evaluating Financial Impact of Selling Electricity through 'TOU PPA' on the CRE Group

Table 6.36 outlines the total revenue that the projects can generate from Solar PV system of 56 kW and 70 kW.

Table 6.36: Scenario 3A, Annual Revenue of Selling electricity through 'TOU PPA'

Scenario 3A 56 kW solar System	Available Energy (kWh)	PPA Rate (£/kWh)	Revenues (£) for 1 year
All year (7:00-16:00)	28,322 kWh	£0.09	£2,548.98
All year (16:00- 24:00)	28,322 kWh	£0.13	£3,681.86
Total PPA Revenues for year 1 (£)			**£6,230.84**

As modelled when the solar PV and storage are not in operation the licenced supplier sells electricity to the host building based on TOUT. Under the 'TOU PPA' approach the host building buys 50% of their electricity at £0.09 per kWh and the other 50% at the £0.13 per kWh (Table 6.37).

Table 6.37: Scenario 3B, Annual Revenue of Selling Electricity through 'TOU PPA'

Scenario 3b 70 kW Solar System	Available Energy (kWh)	PPA Rate (£/kWh)	Revenues (£) for 1 Year
All year (7:00-16:00)	34,124.5 kWh	£0.09	£3,071.20
All year (16:00- 24:00)	34,124.5 kWh	£0.13	£4,436.18
Total Revenues for year 1(£)			**£7,507.385**

6.7.1.1 Evaluating the Financial Impact of 'TOU PPA' on the Host Building Electricity Bills

The 'TOU PPA' approach enables residents of host building to buy and use generated electricity almost all day even when the sun is not shining. In addition, this model provides an opportunity for building tenants to avoid network charges (Figure 6.22).

Under the alternative business a tenant can buy electricity from CRE group through the 'TOU PPA'. For this calculation, it has been assumed that when solar PV and storage are not in operation, the licenced supplier would also supply electricity to the host building with the same rate of 'TOU PPA'.

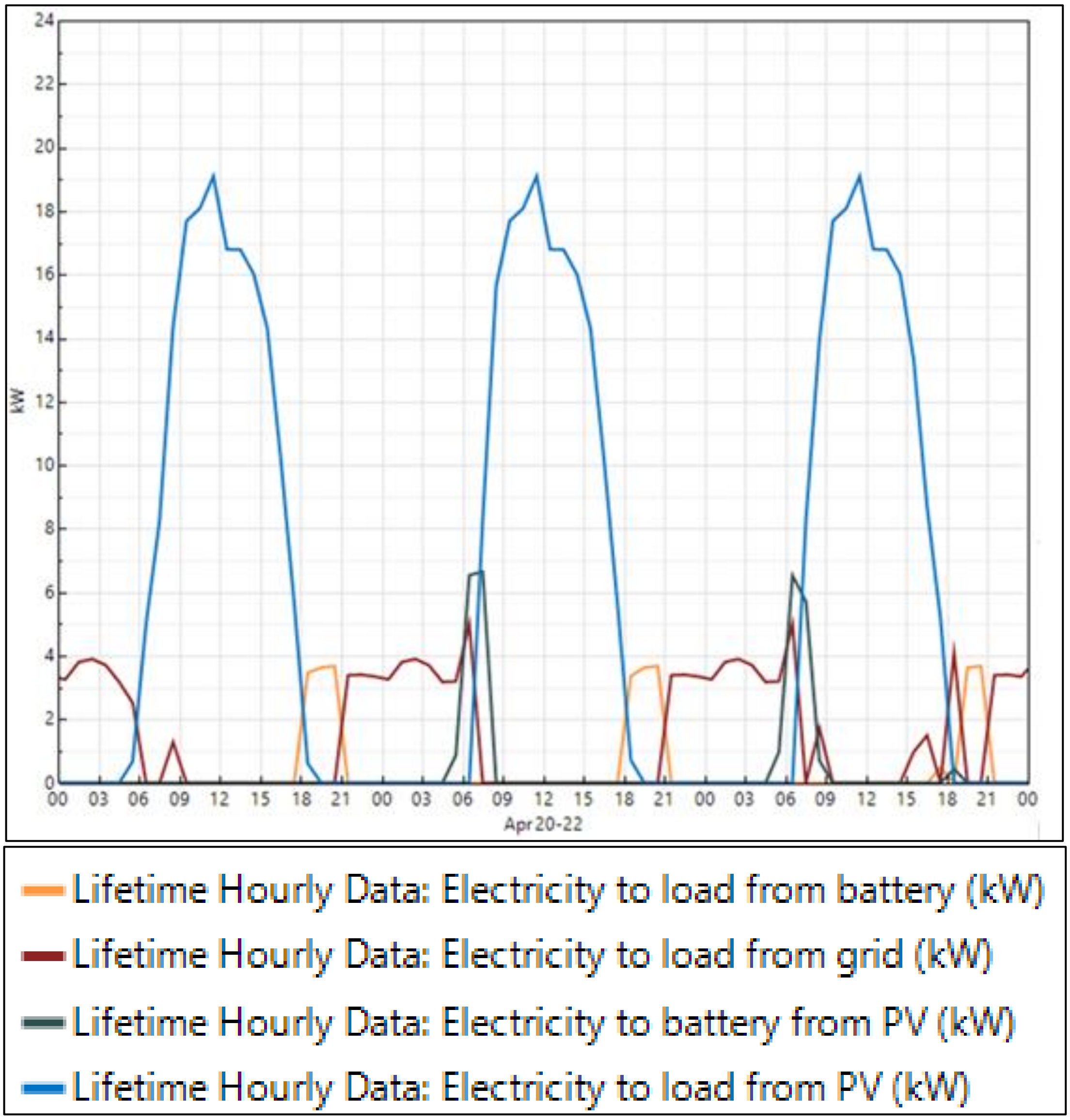

Figure 6.22: CRE Project Providing Electricity to the Host Building Based on 'TOU PPA', Strategy 3.3

Overall, with buying electricity form CRE projects through 'TOU PPA', the host building potentially would save £24,525.29 on their electricity bills (Table 6.38).

Table 6.38: Host Building Tenant's Electricity Cost Savings with System and 'TOU PPA'

Component	**Electricity Bill (£)**
Electricity Bill without System (Year 1)	£30,276.75
Electricity Bill with System And TOU PPA (Year 1)	£5,751.46
Net Savings with System (Year 1)	**£24,525.29**

6.7.2 Combining all Three Sources of Revenue (DSR, STOR and PPA)

The simulation results indicate (Table 6.39) that the proposed alternative business model for community-owned combined solar PV system and electricity storage is most economically attractive if the CRE group can utilise all three source of revenue.

Contracting for both DSR services and STOR may prove slightly challenging as it might get criticised that project are get paid twice once for charging the battery and once for this discharging it, but it is technically feasible.

Table 6.39: Scenario 3 Financial Metric; under the Alternative Business Model, Including DSR, STOR and TOU PPA Revenue

Component	Value for Scenario 3A (56 kW PV), including all revenues	Value for scenario 3B (70 kW PV) including all revenues
Annual Energy Yield (Year 1)	56, 644 kWh	68,249 kWh
Capacity Factor (Year 1)	11%	11.30%
Performance Ratio (Year 1)	0.84	0.84
Battery Efficiency (Incl. Converter + Ancillary)	80.30%	80.30%
LCOE	0.20 £/kWh	0.22 £/kWh
'TOU PPA'	**0.09 & 0.13 £/kWh**	**0.09 & 0.13 £/kWh**
NPV	**£56,578**	**£36,803**
IRR (%)	**4.50%**	**4.50%**
Equity	£68,102	£79,777
Size of Debt	£68,102	£79,777
Capital Cost	£136,203	£159,554

If the CRE project could not contract for all three services the priority should be given to combining DSR and 'TOU PPA' as does generate higher revenue than combining STOR and 'TOU PPA' (Table 6.40).

Table 6.40: Total Gross Revenue all Three Sources Revenue for Year 1 (DSR, STOR and PPA)

Services	Scenario 3A Year 1 Revenue (£)	Scenario 3B Year 1 Revenue (£)
STOR	£1,553	£1,553
DSR for Supplier	£9,282	£9,282
TOU PPA	£6,230	£7,507
Total Gross Revenue (Year 1)	**£17,065**	**£18,342**

6.7.3 Validating the Feasibility and Replicability of the Alternative Business Model

The alternative CRE business model was tested with 34 kW Solar PV and 2 different sizes of storage (28 kWh and 21 kWh) to validate the feasibility and replicability of the model with smaller systems.

Usually, electricity storages with a capacity lower than 50 kWh are not permitted to provide grid services. Consequently, a community-owned solar PV with electricity storage smaller than 50 kWh is only able to benefit from selling electricity through a 'TOU PPA' and providing DSR services for a supplier. However, as Table 6.41 shows the model remains financially viable with both sizes of electricity storage system without providing any grid services. Although, the system with a bigger size of battery (50 kWh) would be potentially more attractive as it offers a more significant NPV.

Table 6.41: Financial Metric for CRE Projects with Smaller System under the Alternative Business Model

Component	Scenario 3 (34 kW Solar PV and 28 kWh Storage)	Scenario 3 (34 kW Solar PV and 21 kWh Storage)
Annual Energy Yield (Year 1)	34,243 kWh	34,243 kWh
Capacity Factor (Year 1)	10.70%	10.70%
Performance Ratio (Year 1)	0.84	0.84
Battery Efficiency (Incl. Converter + Ancillary)	80.30%	80.30%
LCOE	0.17 £/kWh	0.16 £/kWh
TOU PPA	0.09 & 0.13 £/kWh	0.09 & 0.13 £/kWh
NPV	**£36,546.50**	**£25,693**
IRR (%)	4.50%	4.50%
Equity	£42,589	£40,430
Size of debt	£42,589	£40,430
Capital cost	**£85,179**	**£80,859**

6.7.4 Sensitivity Analysis - Scenario 3

It should be noted that the type of ownership of a project under scenario 3 would be different to scenarios 1 and 2. Projects under scenario 3 have community/third party ownership whereas, the projects under scenario 1 and 2 have private ownership. Consequently, the financial parameters that influences the viability of projects under scenario 3 are different to scenarios 1 and 2.

Results of the sensitivity analysis indicated that the developed models in scenario 3 named as ‘Community-Owned Energy Storage’ are sensitives to different parameters including IRR and return on investment (community share) and these parameters would be the key determinants of the profitability of the projects.

To test the robustness of this scenario different ranges of IRR between 4.5% to 6.5% as well as the different rate of return on investment between 4.5% and 6.5% have been modelled.

These sensitivity analyses showed that with an increase in IRR and rate of return on investment, the project NPV also increases, in particular, these changes are significant for projects with bigger Solar PV. For example, if a project with 70 kW solar and 50 kWh storage (named as scenario 3B) has both IRR and the return on investment of 6.5% the project NPV, will be £38,990 which is almost 6% higher than the NPV (£36,803) similar project with both IRR and return on investment of 4.5%. While providing the same rates for a project with 56 kW solar PV and 50 kWh storage (named as scenario 3A) the NPV increases only by 0.06% (APPENDIX I).

Results showed that changes in annual building demand do not have a significant impact on the financial performance of community-owned solar projects. Because, for these type of project, initially, CRE organisation would agree through Power Purchase Agreement (PPA) to provide a certain amount of electricity to a host building based on the size of their system (Solar PV and storage capacity) and annual prediction of solar generation. Consequently, these project revenues are more dependent on solar system generation and storage capacity rather than changes in building demand. Therefore, the scenario evaluated different sizes of solar PV systems and storage to investigate their impact on the financial performance. However, it should be noted that building demand should be considered for this type of project as it is a factor which determines the size of the system unless the building has an exceptional roof area to volume ratio.

6.8 Conclusion

This chapter illustrated that, current community-solar projects will reach grid parity by 2025. However, there are still some questions about the economic sustainability of these projects. Consequently, introducing storage which provides flexibility for the whole electricity value chain and potentially generates income for the existing community-solar business models can technically and economically optimise these business models.

This chapter assessed the techno-economic feasibility of the integration of solar PV and behind meter electricity storage in non-domestic buildings under 3 different scenarios.

The first scenario has shown that an investment in electricity storage for non-domestic buildings will pay off and will have a shorter payback period by maximising self-consumption and avoiding network charges. Additionally, under this model PV systems with storage will have a higher NPV in post-subsidy conditions compared to PV projects without storage.

In the second scenarios, a business model was developed which enables the delivery of a combination of different applications for electricity storage including delivering peak shaving and electricity balancing services. Under this alternative model investment in co-locating electricity storage and a solar PV system in non-domestic buildings would become more economically attractive. Because the developed business model provides an opportunity for the storage owners to generate additional income by delivering grid services as well as reducing their electricity costs.

In the third scenario, based on the results of scenario 1 and scenario 2, a novel and an alternative business model has been developed for community-owned solar projects. Under 'Community-owned Energy Storage', community-owned solar projects become financially viable without the FIT. The designed model can be extended to all community-owned solar projects in all localities. However, 'Community-owned Energy

Storage' business model requires more technical and business expertise than current CRE business model. Thus, in order for this model to work CRE groups should work in partnership with an Aggregator and a local licenced supplier.

CHAPTER 7 CONCLUSIONS

7.1 Introduction

This thesis indicated that business model plays a critical role in the stabilisation and diffusion of a radical innovation such as CRE organisations and the involvement of local people in the transition toward more sustainable energy system in the UK's heavily centralised energy system. It also underlines the importance of institutional and policy framework in shaping and driving of energy transition.

This research showed that the most critical concern for today's CRE sector is the lack of availability of consistent and reliable income, following the major reduction in FIT rates in the UK in 2016. This study illustrated that FIT reduction has been extremely disadvantageous to many CRE projects, predominantly solar PV schemes. The FIT reduction also has made it very difficult for established groups to develop further projects, in particular solar PV projects and virtually impossible for groups that are not yet established. Consequently, the most pressing challenge for CRE projects is to create and implement alternative business models which would allow a reliable income stream.

The primary aim of this thesis was to accelerate the formation and growth of CRE initiatives in the UK by developing an innovative business model approach that CRE groups, in particular community-owned solar projects, can take up and progress without any subsidies. The purpose of this chapter is to outline how this thesis has answered the research questions and addressed the aim and objectives outlined in CHAPTER 1. It highlights the original contribution to the knowledge followed by policy recommendation and the future research requirements.

7.2 Achievement of Research Objectives

The research questions have been broken down into seven objectives. This section illustrates how this thesis has answered the research questions and addressed the aim and objectives of this thesis (outlined in CHAPTER 1).

Objective 1: To critically evaluate the policy, strategy and existing literature on UK CRE projects to identify the factors that have an influence on the slow growth of the CRE sector.

This objective has been addressed in CHAPTER 2 and answered question 1 (outlined in CHAPTER 1). The literature review emphasised the lack of robust strategic and committed policy support to promote CRE projects. Instead, most UK policies were more committed to helping develop and support centralised large-scale RE supply through utilities, rather than encouraging diversity regarding scale and ownership models. This study in CHAPTER 4 stressed that although the UK Government has supported the sector via different public subsidies and grants, this support has clearly not been consistent. Inconsistency and contradiction in CRE policy support is the key reason for the slow progress of projects in the UK.

Objective 2: To Identify and evaluate emerging alternative business models, taking into account the available resources and financial risks or benefits.

This objective was approached in CHAPTER 2 (Section 2.9) and CHAPTER 5 (Section 5.4.2). Question 2 was also answered by identifying combining solar PV and storage as the approach that CRE organisations can potentially take to progress based on the UK's culture, business and energy market legalisation. This study has underlined that electricity storage can play a critical role in optimising existing CRE model and increase grid reliability particularly in areas where there is high RE penetration.

Objective 3: Establish a database of existing CRE projects and their activities to provide in-depth assessment of alternative and innovative business models by exploring fundamental aspects of their business model structure.

This study was successful in addressing this objective by establishing a database comprising of 72 CRE organisations around the UK. The result of this objective has presented in CHAPTER 4. By addressing this objective, this study filled the gap in original empirical data on the current scale of CRE activities after the curtailment of RE support schemes. Furthermore, this study has successfully contributed to the literature by assessing the UK's CRE groups from four fundamental areas of the business model Canvas, while previous research only focused on a few elements of the business model. This way of fully mapping the different aspects of the business model provided an in-depth understanding of the character of the UK's CRE sector, and allowed this study to identify RE generation in particular solar PV alongside battery storage as an alternative business model development of future CRE projects without FIT.

Objective 4: Evaluate the key economic and socio-technical factors that contribute to the success of the CRE sector, and identify the perceived challenges faced during their future development

This study was successful in meeting this objective, the result of the analyses presented in CHAPTER 4 (Section 4.4 and 4.5) showed that, the lack of structured policy support, as well as the difficulty in identifying viable sites, were the greatest challenges faced by the UK's CRE sector during the project development stage (before RE policy changes). Nevertheless, this study has shown that recent policy measures such as the Community Energy Strategy and financial incentive schemes (FIT, UCEF and RCEF) have helped to overcome these challenges to some extent and foster the development of the existing CRE projects.

Objective 5: Evaluate the impact of the curtailment of RE support mechanisms in 2015 on the development of the UK's CRE sector and identify the perceived challenges facing their future development.

As the results presented in CHAPTER 5 indicate, this research was successful in meeting this objective. This study showed that the recent RE policy uncertainty has been extremely disadvantageous to many CRE projects, predominantly solar PV schemes. Since, the majority of these projects were mostly dependent on grants and public subsidies for the viability of their projects which, are not a reliable source of income.

This study indicated that under new RE policy conditions only a few large organisations are experimenting and innovating models for further development while the majority focus on surviving rather than developing. This study identified that the main perceived challenges facing the future development of CRE projects are the lack of profitability of the existing models also the lack of established and viable business models for new approaches.

Objective 6: Run techno-economic analyses to investigate whether the integration of solar PV and electricity storage can be structured to provide demand-side response services, enabling peak shaving and electricity balancing services and in turn, create a feasible and financially viable model for community-owned solar PV projects in the post-subsidy condition.

This study successfully met this objective, as demonstrated by the result of the analyses presented in CHAPTER 6 (Section 6.4.1 and 6.5). The results of this objective have shown that investment in combining electricity storage and a solar PV system for non-domestic buildings will pay back before the system reaches end-life and that a shorter payback period can be achieved by maximising self-consumption, peak shaving and providing DSR services through an Aggregator. Furthermore, the results of this objective provide a background understanding of revenue streams modelling of ‘Community-owned Energy Storage’ model.

Objective 7: Use the System Advisor model developed by NREL as a simulation tool to develop and validate a business model for community-owned solar projects, the most common types of existing CRE projects under the new policy conditions.

As the simulation results presented in CHAPTER 6 show (particularly section 6.6), this research developed a novel business model for community-owned solar projects in the UK. Under the innovative model, these projects become financially viable without the FIT. The designed model can be extended to all community-owned solar projects in all localities.

This model can potentially accelerate development of new community-owned solar projects in post-subsidy conditions enabling these projects to be economically viable without the help of any incentives and grants (addressed question 3).

7.3 Original Contribution to Knowledge

This section outlines the contributions that this thesis has made to on-going debate in the socio-technical transition, business model, business model innovation and community energy.

7.3.1 Contribution to Industrial Practices

This study contributes to industrial practices by:

I. Designing a novel business model for the operation of community-owned solar PV in the UK which makes these projects self-sustaining. This model enables community and citizen investors to be involved in the generation of RE and grid balancing services even when grants and subsidies are not available.

II. Developing and introducing a new Power Purchase Agreement (PPA) named as 'TOU PPA' which enables the sale of electricity directly to host premises, where RE and storage technology are installed, based on the time of electricity use.

III. Developing a viable and attractive business model for integration of solar PV and storage systems: this model enables small-scale RE projects to be involved in providing balancing services for transmission system operator (National Grid).

7.3.2 Empirical and Knowledge Contribution

This thesis makes empirical contributions by:

I. Assessing the UK's CRE groups from four fundamental areas of the business model Canvas, with previous research only on few elements of the business model.
II. Providing empirical evidence on the impact of the major institutional changes on grassroots innovation in particular CRE sector.
III. Providing empirical data on the current scale of CRE activities after the curtailment of RE support schemes.
IV. Providing empirical evidence that institutional and policy framework is a significant driver for sustainability transitions and business model innovation.

7.4 Recommendation and Policy Implication for Research Findings

This study indicated that combining solar PV and electricity storage will provide a sustainable model for CRE projects in the future. If the UK government wants CRE groups to play a role in the UK's energy transition, it is essential that it provides the appropriate support needed by these groups to develop an alternative and innovative business model. In order for 'Community-owned Energy Storage' business model (which has been proposed in this study) to be potentially rolled out, the strategies proposed are:

i. The UK's localised renewable energy schemes must be enabled to effectively and efficiently sell their electricity directly to local customers and tenants. Therefore this study proposes that the UK government should promote and facilitate the Time of Use Power Purchase Agreement ('TOU PPA') for CRE projects.

ii. The UK government should facilitate grid access and reduce connection charges for CRE projects.

iii. In order to reduce risks in developing an innovative business model including 'Community-owned Energy Storage', CRE groups should have access to zero interest loans for part of their projects.

iv. Alternatively, the UK government should bring back the Urban Community Energy Fund (UCEF) which would provide 'contingent' loan for the feasibility study and promoting 'Community-owned Energy Storage' projects, until the cost of battery storage steadily decreases.

v. The UK's energy suppliers should involve localised renewable energy schemes with storage in providing demand-side response services. This approach would be a 'win-win' situation for both parties, as it offers a potential for an energy supplier to reduce their expensive balancing costs and increases the viability of CRE projects.

7.5 Opportunities for Future Research

Some potential research scopes could build on the analysis in this PhD thesis and could benefit from further research, as follows:

One of the key results of this study was developing alternative business models for distributed and localised renewable energy schemes, and validating the model in practice was out of scope this study, due to research design and resource limitations.

Consequently, it would be advantageous to validate this business model (community-owned Energy Storage) in real case studies in different non-domestic buildings with different building loads.

This study used the existing weather data for simulations. It would also be advantageous to evaluate all developed simulations with future weather prediction in order to fully recognise and establish the relationship between the future solar irradiances and respective locational temperatures, provided that there is any relation. These further simulations were out of the scope of this study.

This study only focused on the techno-economic analysis of combining solar PV and storage and Life Cycle Assessment (LCA) was outside of the scope of this study. However, it would be valuable to run indicative carbon life cycle study and fully detailed LCA. Both should include all life cycle stages and different end-of-life scenarios (reuse, recycling and disposal in a landfill) to evaluate the overall life cycle impact of combined PV and battery storage in the built environment.

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APPENDIX A: ETHICS APPROVAL LETTER

London South Bank
University

Direct line: 02 07 815 7276
E-mail: kaluaray@lsbu.ac.uk
Ref: Ethics BEA 1-P

Monday 1st August 2016

Dear Pegah

RE: Developing Viable Self-Sustaining Community Energy in the UK through A New Business Model

Thank you for submitting this proposal.

I am pleased to inform you that full Chair's Approval has been given by Dr Yamuna Kaluarachchi, on behalf of the School of The Built environment & Architecture.

I wish you every success with your research.

Yours sincerely,

Dr Yamuna Kaluarachchi

Chair, Research Ethics Coordinator
School of The Built environment & Architecture.

APPENDIX B: WEB-BASED SURVEY QUESTIONS

Developing Viable Self-Sustaining Community Energy in the UK

Page 1: Page 1

Your Organisation

1. Organisation Name:

2. Year of official establishment:

3. Location (nearest town/post code) of your organisation ?

4. Which one of the following best describe your Community Energy group/projects? * *Required*

Please select no more than 1 answer(s).

1 / 15

- [ ] Owned by a local community
- [ ] Owned by geographical communities
- [ ] Unincorporated group whose at the early stages
- [ ] Network of local energy projects
- [ ] Intermediary/broker who initiate new community energy projects and provide training and advice for community groups
- [ ] Voluntary/informal association including a group of individuals who entered into an agreement, to form a community energy organisation
- [ ] Other

4.a. If you selected Other, please specify:

5. Is community energy projects is the main business activity of your organisation?

- ○ Yes
- ○ No

6. Please identify what stage is your organisation at?(Tick All that apply)

Please select no more than 5 answer(s).

- [ ] Feasibility stage
- [ ] Pre-planning stage
- [ ] Planning stage
- [ ] Design/installation/construction stage
- [ ] Operational stage
- [ ] Not active

6.a. If you selected Not active, please specify the reason :

7. What is the ownership/legal structure of your group/project?(Tick all that apply) * Required

- [ ] Cooperatives
- [ ] Industrial Provident societies
- [ ] Community Interest companies limited by shares
- [ ] Community Interest companies limited by guarantee
- [ ] Community benefit societies
- [ ] Cooperative Societies
- [ ] Social enterprise
- [ ] Development trust
- [ ] Joint venture
- [ ] Shared revenue
- [ ] Split ownership
- [ ] Charity
- [ ] Un-constituted group

7.a. If your organisation is cooperative how many members does your cooperative have?

- [ ] 0 up to 50 members
- [ ] 100 up to 500 members
- [ ] 501 up to 1000 members
- [ ] 1001 to 1500 members

- [ ] Over 1500 members

Your existing projects

8. In which phase of your projects did you raise capital?(Tick all that apply) * *Required*

Please select no more than 4 answer(s).

- [ ] Feasibility stage
- [ ] Pre-planning stage
- [ ] Planning stage
- [ ] Design/Installation/Construction stage
- [ ] Operational stage

9. What form of finance raising did you use? * *Required*

- [ ] Solely community shares offer
- [ ] Solely community bonds issue
- [ ] Non-grant funding(e.g.loan,shares)
- [ ] Grant funding
- [ ] Gift/ Charitable funding
- [ ] Sponsorship
- [ ] Solely Subsidies (e.g Feed in Tariff income)
- [ ] Mixture of Subsidies and Non-grant funding(e.g.loan , shares)
- [ ] Other

9.a. If you selected Other, please specify:

10. In the case of using Grants/Loans which source of funding did your group/projects use?(Tick all that apply)

Please select no more than 5 answer(s).

- ☐ Government Funding Scheme
- ☐ Local Authority Funding Scheme
- ☐ Community Benefit Fund
- ☐ Big lottery fund/National lottery
- ☐ Social/private loans
- ☐ Commercial loans
- ☐ Other

10.a. If you selected Other, please specify:

11. Which of the following provides revenue for your projects/group?(Tick all that apply)

Please select no more than 5 answer(s).

- ☐ Public subsidies(e.g Feed in Tariff, Renewable Heat Incentive)
- ☐ Mixture of public subsidies payment and saleof electricity/Heat
- ☐ Only sale energy(heat and power) to the community

- [ ] No income
- [ ] Other Commercial income

12. How many employees (including part-time and full-time) does your community group/project have?

- ( ) None
- ( ) 1 up to 3
- ( ) 4 up to 10
- ( ) Over than 10

13. How many volunteers work for your project/group?

- ( ) None
- ( ) 1 up to 3
- ( ) 4 up to 10
- ( ) Over than 10

13.a. How do/will investors benefit from their membership of community energy projects?(Tick all that apply)

Please select no more than 6 answer(s).

- [ ] Receiving interest on their investment
- [ ] Using generated energy on site
- [ ] Buying generated energy at a lower price than the market price
- [ ] Saving on their energy bills
- [ ] Benefiting from a fixed price electricity tariff
- [ ] Contributing to corporate social responsibility
- [ ] Other

13.a.i. If you selected Other, please specify:

14. What type of activities does your community energy group /project undertake? (Tick all that apply)

- Energy saving projects
- Promoting energy efficiency through behavior change
- Awareness raising/Energy advice
- Generating electricity/Generating heat
- Sell non-tradable shares to members of the community
- Enterprising community-led organisations
- Provide consultancy to community energy projects

14.a. Please identify your organisations total installed capacity(kW)? *Optional*

Please select no more than 1 answer(s).

- Less than 50 kW
- Between 51 and 500kW
- Between 501 and 5000kW
- Over than 5000kW

14.b. What type of technology do you use for energy generation?(Tick all that apply) *Optional*

Please select no more than 6 answer(s).

- Wind

- [ ] SolarPV
- [ ] Biomass
- [ ] Hydro
- [ ] Anaerobic Digestion
- [ ] Micro CHP
- [ ] Solar water heating
- [ ] Solar thermal
- [ ] Ground source heat pump

14.b.i. How long did your project take to develop?

____

15. The following factors have been identified as challenges to the Community Energy (CE) projects development in the UK please rate them on its challenge to your projects prior or during setting up?

Please don't select more than 1 answer(s) per row.

	Not challenging	Somewhat challenging	Extremely challenging
Finding investor	☐	☐	☐
Finding funding	☐	☐	☐
Fundraising	☐	☐	☐
Finding viable sites	☐	☐	☐
Planning permissions	☐	☐	☐
Access and use available funding	☐	☐	☐
Finding volunteers to deliver project	☐	☐	☐
Lack of financial support	☐	☐	☐
Lack of policy support	☐	☐	☐

Lack of skill and knowledge to deliver project	☐	☐	☐
Community engagement	☐	☐	☐
Public opposition	☐	☐	☐
Network connection	☐	☐	☐
Technical feasibility	☐	☐	☐

16. The following has been identified as success factor for CE projects please ate them on its effectiveness on the success of your group/projects prior or luring setting up?

lease don't select more than 1 answer(s) per row.

	Not effective	Somewhat effective	Extremely effective	Did not use
Government funding scheme	☐	☐	☐	☐
Available funding from commercial lender	☐	☐	☐	☐
Available funding from social lender	☐	☐	☐	☐
Feed- in Tariff payment	☐	☐	☐	☐
Green deal communities	☐	☐	☐	☐
Renewable Heat Incentives payment	☐	☐	☐	☐
Renewable energy obligation	☐	☐	☐	☐
Tax relief scheme	☐	☐	☐	☐
Supports from local suppliers	☐	☐	☐	☐
Supports from local authority/councils	☐	☐	☐	☐

Available information /resources for supporting CRE (e.g center for sustainable energy)	☐	☐	☐	☐
Membership of local and regional community energy network	☐	☐	☐	☐

mpact of post-2015 policy changes on CE activities

17. What policies changes already affecting/will affect your project the most?

- ○ Dramatic reduction to FiT rate
- ○ Changes to tax relief scheme for CE projects
- ○ The removal of pre-accreditation for small scale renewables projects
- ○ Removal Green deal for communities projects

17.a. Please describe how?

17.b. Please give details about any projects that did not go ahed or adversely ıffected by post-2015 policy changes?

Page 2: P.2

18. What are the main challanges for your group/projects under new policy regime? (Tick all that apply) *Optional*

Please select no more than 6 answer(s).

- ☐ Fundraising
- ☐ Finding new business models for new projects
- ☐ Getting planning permission for new sites
- ☐ Engaging community
- ☐ Finding funding
- ☐ Finding investor
- ☐ Lack of policy support
- ☐ Difficulty in raising capital and lack of viable business models
- ☐ Other

18.a. If you selected Other, please specify:

19. In your opinion which of following business models might best support community energy projects and replace the public subsidies business model?

Please select no more than 2 answer(s).

- ☐ Local supply(sell power directly to the local community)
- ☐ Long term power purchase agreement
- ☐ Battery storage
- ☐ Esco (Energy Service company)
- ☐ Self supply/private wire arrangement sell power to community without transmitting through public network
- ☐ Local aggregation and demand side respond

☐ No opinion

20. Do you think current fundraising(Cooperative, crowdfunding) will be viable for projects under new policy regime?

○ Yes
○ No

21. Has your group developed or planning to develop any further projects under new FiT regime(2016) and tax relief changes?

Please select no more than 1 answer(s).
☐ Yes
☐ No

21.a. What business model you planning to pursue?

○ Local supply(sell power directly to the local community)
○ Long term power purchase agreement
○ Battery storage
○ Esco (Energy Service company)
○ FiT business model
○ Local aggregation and demand side respond
○ Self supply/private wire arrangement sell power to community without transmitting through public network
○ Confidential
○ Other

21.a.i. If you selected Other, please specify:

21.b. What type of activities does/did your group undertake?(Tick all that apply)

Please select at least 5 answer(s).

- [ ] Electricity generation from Wind
- [ ] Electricity generation from PV
- [ ] Heat generation
- [ ] Energy efficiency
- [ ] Finance and developing Community Energy organisation
- [ ] Other

21.b.i. If you selected Other, please specify:

22. Are you willing to take part in a semi-structured interview for this research?
Optional

- ( ) Yes
- ( ) No

22.a. If you selected Yes, please leave your name and email.

APPENDIX C: PARTICIPANT INFORMATION SHEET

London South Bank
University

Participant Information Sheet

Study Title

Developing Viable Self-Sustaining Community Energy in the UK through A New Business Model

Invitation to Take Part in a Research Project

You are being invited to take part in "**Developing Viable Self-Sustaining Community Energy in the UK through A New Business Model** "study. Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully.

Purpose of Research:

This PhD research is undertaken by Pegah Mirzania at the school of Built Environment and Architecture, London South Bank University, London, UK. The aim of this research is to evaluate ways to accelerate the formation and growth of community renewable energy (CRE) projects in the UK by developing new business models. The research discusses the key following areas:

- Why has community energy progress in the UK been so limited?
- Many operating community-based renewable energy projects that were grant funded. The question is how do we make projects work when grants and subsidies are not available?

Why Have I Been Invited To Participate?

This PhD research using mixed methods and one of data collection method are use of semi-structured interview. The data only will be used to help form and analysis community energy development in the UK.

Do I Have To Take Part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What Will Happen To Me If I Take Part?

The interview will use pre-defined question and will take approximately 60 mins. There will be no costs associated with the study other than time.

What Are The Possible Benefits of Taking Part?

Taking part in this Study will give you an opportunity to provide your views on Community renewable energy project development and what key issues relating to the field. Your participation provides a valuable source of information and evidence how community energy project developed in the UK. The survey data will be used to analyse community renewable development and further understand the topic.

Will The Data Collected In This Study Be Kept Confidential?

Yes, all information collected during the study will be kept strictly confidential. The survey will not collect sensitive personal information (e.g ethnicity, political views, and religious belief).The study will not be used for any other purpose than this Ph.D. and related academic publications.

What Will Happen To The Results Of The Research Study?

The study data will be used to analysis community renewable energy development in the UK. The data will be used in the final thesis of the PhD and help to analyse community renewable projects in the UK, particularly relating to the future of community renewable projects after reducing or removal of public subsidies (e.g Feed in Tariff, Green deal), key success factors, barriers, and potential business models for the development of these projects. It is expected that some of the PhD results will be published in academic journals such as Energy Policy.

Who is Organising and Funding the Research?

I am as Ph.D. researcher at London South Bank University, School of Built Environment and Architecture

Who Has Reviewed The Study?

This research has been approved by Research Ethics Committee at London South Bank University.

Contact for Further Information

If you have any question relating to this PhD research or the way it has been conducted please contact:

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Thank you for taking time and reading this information Sheet

APPENDIX D: INTERVIEW TOPIC GUIDE, ACTIVE CRE ORGANISATION

Interview Topic Guide Developing Viable Self-Sustaining Community Energy in the UK through A New Business Model

Interview:
I would like to find out more about your experience about community energy project including challenges you have been faced during project development in the UK and what it has been like: Could you please tell more about:

1. **Brief History:**

   a) Who were the key partners (Key funders) for your projects?

   . . . .

   b) Where did you initially get funding from?

   . . . .

   c) Total install capacity?

   . . . .

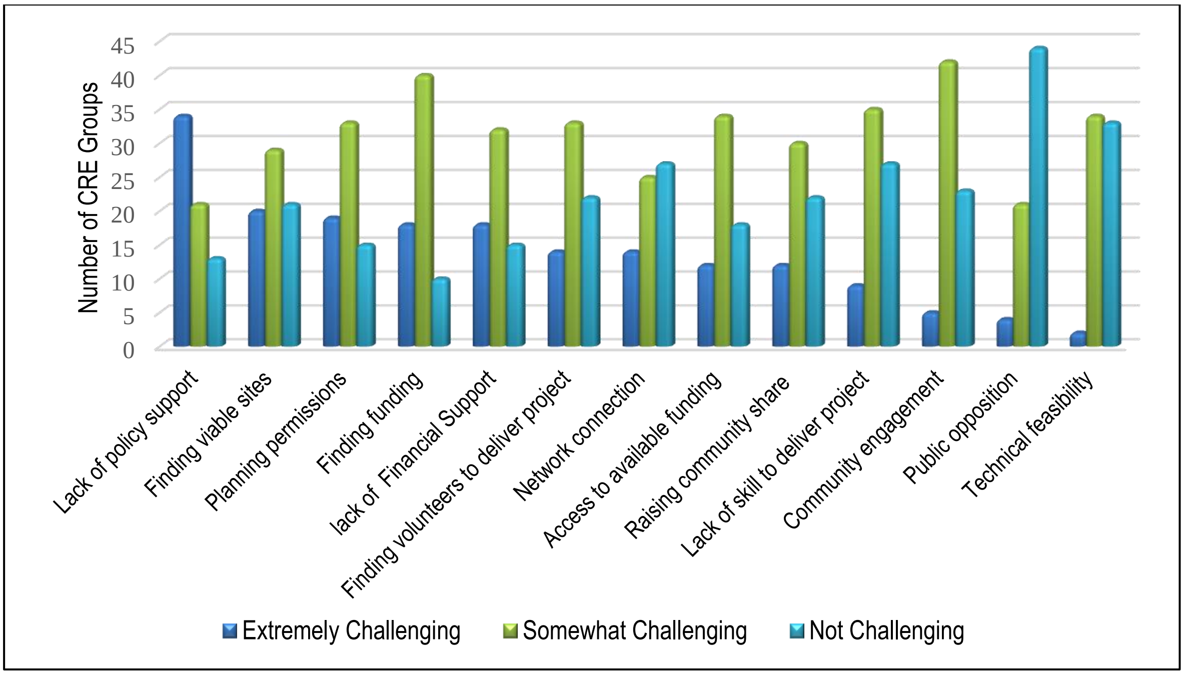
2. Existing Projects:

   a) What were the main challenges/ barriers for your recent projects development? How did you overcome them? .

   . . . .

   b) Based on the survey I have done in September 2016 I came up with Lack of policy supports in particular lack of project supports and funding viable sites and planning permission and fundraising as main barriers for existing projects do you agree with results? Can you give me your opinion on that?

   . . . .



c) What about planning permission did you need planning permission or it was part of permitted development?

. . . .

d) What factor do you think was the catalysers of Solar projects in the UK why do you think solar projects has been developed more than other technologies in the UK?

. . . .

3. Post Policy Changes:

a) What were the main challenges for your group projects under new policy regime?

. . . .

.

b) What were the main barriers for your group projects under new policy regime?

. . . .

c) How do you think the recent policies change (e.g. dramatic reduction to FIT and changes to tax relief scheme) have affected Community energy sector and your organisation?

. . . .

d) How do you think effect recent policy changes on community energy sector can be overcome and mitigated?

. . . .

e) What are the expectations for the future development?

. . . .

f) Are there any further questions you think I should ask?

. . . .

g) Do you have any recommendations for further people I should speak about my research?

. . . .

h) Anything else to add?

. . . .

THANK YOU

APPENDIX E: INTERVIEW TOPIC GUIDE, Non-ACTIVE CRE ORGANISATION

Interview Topic Guide Developing Viable Self-Sustaining Community Energy in the UK through A New Business Model

Brief History

1. **Your organisation background:**
   a) Organisation Name
   . . . .
   b) Your role in community energy group?
   . . . .

2. Main challenges during project development

- **a)** Please specify what are the main reasons that your organisation is not active at the moment?
  . . . .
- b) What makes network connection extremely challenging?
  . . . .
- c) In general what challenge do you think currently faced all CRE projects in the UK?
  . . . .
.

3. Challenges to fundraising:

a) Who were the key partners (Key funders) for the project?
. . . .
b) How much was initial start-up funds for the scheme?
. . . .
c) What were the main way of raising finance for projects development (grant funding, government scheme, share offers, bonds)?
. . . .
d) Please specify source of funding in each phase of your project development?
. . . .
e) In which phase you couldn't manage to raise finance? What were the main reasons?

. . . .

f) How those effect your FIT pre-accreditation?

. . . .

4. What are the expectations for the future development?

. . . .

5. Anything else to add.

. . . .

THANK YOU

APPENDIX F: NUMBER OF CRE SITES/SCHEME IN THE STUDY

Project phase	Number of sites (Total 502)
Non-active sites	9
Operational sites	69
Pre-installation	0
Installation	32
Feasibility	15
Planning	7
Unknown	363
Pre-planning	7

APPENDIX G: SENSITIVITY ANALYSIS -SCENARIO 1

G1: Example of Analysis with Battery Replacement Costs

Because, the solar PV lifetime is between 20- 25 years therefore, an analysis has been also conducted over 25 years to estimate overall lifetime solar PV which include battery storage replacement costs. The assumption for the battery replacement cost has been conducted according to KPMG LLP (2016) report, which predicted that the full cost of Lithium-Ion Battery will decrease 12% per annum. Consequently, the cost of battery replacement in 2033 will be £87.01 (with a battery life of 15 years).

Scenario 1A; Financial Metric of Integrating of Solar PV (56 kW) with Electricity Storage (42 kWh) Counting Battery Replacement Costs Over 25 Years Projects.

Component	Strategy 1.1 with Battery Replacement	Strategy 1.2 with Battery Replacement	Strategy 1.3 with Battery Replacement
Annual Energy Yield (Year 1)	56, 644 kWh	56, 644 kWh	56, 644 kWh
Capacity Factor (Year 1)	11%	11%	11%
Performance Ratio (Year 1)	0.84	0.84	0.84
Battery Efficiency (Incl. Converter + Ancillary)	76.8%	76.8%	76.8%
LCOE	0.233 £/kWh	0.24 £/kWh	0.23 £/kWh
Electricity Bill Without System (Year 1)	£30,297	£30,297	£30,297
Electricity Bill With System (Year 1)	£14,034	£2,861	£3,692
Net Savings With System (Year 1)	£16,262	£27,436	£26,605
NPV	£73,493	£151,545	£256,283
Payback Period	9.7 years	6.0 years	6.3 years
Capital Cost	£131,92	£131,92	£131,92

As the table indicates replacing battery storage increase the operating and maintenance costs and increases the payback period. The business case can still be viable as it maximises the use of solar generation over the lifetime of PV, resulting in higher NPV. However, with battery replacement costs the business model is not financially attractive due to a more extended payback period.

G2: FINANCIAL SENSITIVITY ANALYSIS

Financial Analysis for Scenario 1A with Strategy 1

Electricity Bill Escalation Rate (%/Year)	Inflation Rate (%/Year)	Real Discount rate (%/Year)	NPV (£)	Payback Period (Years)
3%	2%	4%	£61,558.35	7.7 Years
3%	2.50%	4.50%	£61,777.73	7.6 years
3%	3%	5%	£61,719.83	7.5 years
3%	3.50%	5.50%	£61,431.15	7.4 years
3%	4%	6%	£60,951.30	7.3 years
4%	2%	4%	£73,646.78	7.5 years
4%	2.50%	4.50%	£73,160.93	7.4 years
4%	3%	5%	£72,445.28	7.3 years
4%	3.50%	5.50%	£71,542.65	7.2 years
4%	4%	6%	£70,489.50	7.1 years
5%	2%	4%	£86,719.50	7.29 years
5%	2.50%	4.50%	£85,460.25	7.2 years
5%	3%	5%	£84,023.25	7.1 years
5%	3.50%	5.50%	£82,447.50	7.0 years
5%	4%	6%	£80,767.50	6.9 years

Financial Analysis for Scenario 1A with Strategy 2

Electricity Bill Escalation Rate (%/Year)	Inflation Rate (%/Year)	Real Discount Rate (%/Year)	NPV (£)	Payback Period
3%	2%	4%	£147,426.00	4.61 years
3%	2.50%	4.50%	£143,397.25	4.57 years
3%	3%	5%	£145,397.25	4.54 yeas
3%	3.50%	5.50%	£143,167.50	4.50 years
3%	4%	6%	£140,779.50	4.47 years
4%	2%	4%	£138,270.75	4 53 years
4%	2.50%	4.50%	£162,354.75	4.50 years
4%	3%	5%	£159,521.25	4.46 years
4%	3.50%	5.50%	£156,537.75	4.43 years
4%	4%	6%	£153,443.25	4.33 years
5%	2%	4%	£163,089.75	4.46 years
5%	2.50%	4.50%	£178,356.75	4.43 years
5%	3%	5%	£174,647.25	4.39 years
5%	3.50%	5.50%	£170,843.25	4.36 years
5%	**4%**	**6%**	£166,980.75	**4.33 years**

Financial Analysis for Scenario 1A with Strategy 3

Electricity Bill Escalation Rate (%/Year)	**Inflation Rate (%/Year)**	**Real Discount Rate (%/Year)**	**NPV (£)**	**Payback Period**
3%	2%	4%	£196,496.25	4.88 years
3%	2.50%	4.50%	£190,952.25	4.84 years
3%	3%	5%	£185,460.00	4.89 years
3%	3.50%	5.50%	£180,044.25	4.84 years
3%	4%	6%	£174,723.00	4.79 years
4%	2%	4%	£217,866.00	4.75 years
4%	2.50%	4.50%	£211,055.25	4.71 years
4%	3%	5%	£204,382.50	4.79 years
4%	3.50%	5.50%	£197,865.75	4.75 years
4%	4%	6%	£191,517.75	4.71 years
5%	**2%**	**4%**	£241,020.75	**4.67 years**
5%	2.50%	4.50%	£232,817.25	4.64 years
5%	3%	5%	£224,847	4.63 years
5%	3.50%	5.50%	**£217,122**	4.60 years
5%	**4%**	**6%**	**£209,648.25**	**4. 56 years**

G3: SENSITIVITY ANALYSIS WITH DIFFERENT BUILDING DEMAND

Scenario 1A (56 kW PV And 42 kWh Storage), Strategy 1.1

Component	Actual Building Demand	Building with Lower Electricity Demand	Higher Building Demand
Building Demand	53,862 kWh	45,782 kWh	61,941 kWh
NPV	£72,423	£64,170.75	£76,081.50
Payback period	7.3 years	7.7 years	7.1 years

Scenario 1A (56 kW PV and 42 kWh) storage, Strategy 1.2

Component	Actual Building Demand	lower Building Demand	Higher Building Demand
Building Demand	53,862 kWh	45,782 kWh	61,941 kWh
NPV	£159,521	£101,835	£159,543
Payback period	**4.5 years**	**5.8 years**	**4.3 years**

Scenario 1A (56 kW PV and 42 kWh storage), Strategy 1.3

Component	Actual Building Demand	Building Demand	Higher Building Demand
Building Demand	53,862 kWh	45,782 kWh	61,941 kWh
NPV	£211,055	£178,461	£249,030
Payback period	**4.7 years**	**5.3 years**	**4.2 years**

Scenario 1B (70 kW PV and 42 kWh Storage), Strategy 1.1

Component	Actual Building Demand	Building with Lower Electricity Demand	Building with Higher Electricity Demand
Building Demand	53,862 kWh	45,782.36 kWh	61,941 kWh
NPV	£71,846	£64,227	£86,422.50
Payback Period	**7.7 years**	**8.1 years**	**7.2 years**

Scenario 1B (70 kW PV and 42 kWh storage) Strategy 1.2

Component	Actual Building Demand	Building with Lower Electricity Demand	Building with Higher Electricity Demand
Building Demand	53,862 kWh	45,782 kWh	61,941 kWh
NPV	£140,127	£121,064.25	£173,063.25
Payback Period	**6.6 years**	**7.4 years**	**5.5 years**

Scenario 1B (70 kW PV and 42 kWh storage) Strategy 1.3

Component	Actual Building Demand	Building with Lower Electricity Demand	Building with Higher Electricity Demand
Building Demand	53,862 kWh	45,782 kWh	61,941 kWh
NPV	£200,947	£178,461	£252,486
Payback Period	**5.4 years**	**6.2 years**	**4.5 years**

APPENDIX H: SENSITIVITY ANALYSIS - SCENARIO 2

H1: SENSITIVITY ANALYSIS WITH DIFFERENT STOR AND FFR REVENUES

Scenario 2A (56 kW PV and 50 kWh storage), Strategy 2.1 (FFR Revenue)

Component	Actual FRR Gross Revenue	FFR Revenue (15% Higher)	FFR Revenue (20% Higher)	FFR Revenue (25% Higher)
FFR Revenue	£20.8	£23.92	£24.96	£26
NPV (Peak shaving & FFR)	£243,192	£243,403	£243,412	£243,421
Payback Period	4.7 Years	4.65 Years	4.65 Years	4.6 Years

Scenario 2B (56 kW PV and 50 kWh storage), Strategy 2.1 (FFR Revenue)

Component	Actual FFR Gross Revenue	FFR Revenue (15% Higher)	FFR Revenue (20% Higher)	STOR Revenue (25% Higher)
FFR Revenue	£20.8	£23.92	£24.96	£26
NPV (Peak shaving & FFR)	£184,656	£184,938	£184,951	£184,951
Payback Period	5.8 Years	5.8 Years	5.8 Years	5.8 Years

Scenario 2A (56 kW PV and 50 kWh Storage), Strategy 2.2 (STOR Revenue)

Component	Actual STOR Gross Revenue	STOR Revenue (15% Higher)	STOR Revenue (20% Higher)	STOR Revenue (25% Higher)
STOR Revenue	£1,462	£1,681.30	£1,754.40	£1,827.50
NPV (Peak shaving & STOR)	£256,343	£258,348	£258,992	£259,636
Payback period	4.4 Years	4.4 Years	4.3 Years	4.2 Years

Scenario 2B (56 kW PV and 50 kWh storage), Strategy 2.2 (STOR Revenue)

Component	Actual STOR Gross Revenue	STOR Revenue (15% Higher)	STOR Revenue (20% Higher)	STOR Revenue (25% Higher)
STOR Revenue	£1,462	£1,681.30	£1,754.40	£1,827.50
NPV (Peak shaving &STOR)	£241,990	£243,637	£244,281	£244,984
Payback period	4.9 Years	4.7 Years	4.6 Years	4.6 Years

H2: SCENARIO 2 WITH 15% HIGHER AND LOWER BUILDING DEMAND

Scenario 2A (56 kW PV and 50 kWh Storage)

Component	Actual Building Demand	Building with Lower Electricity Demand	Higher Building Demand
Building Demand	53,862 kWh	45,782 kWh	61,941 kWh
NPV	£256,343.25	£259,368	£301,674
Payback period	4.4 Years	5.3 Years	4 Years

Scenario 2B (70 kW PV and 50 kWh Storage)

Component	Actual Building Demand	Building with Lower Electricity Demand	Higher Building Demand
Building Demand	53,862 kWh	45,782 kWh	61,941 kWh
NPV	£241,990.50	£241,194	£313,338.75
Payback period	4.9 Years	5.9 Years	4.5 Years

APPENDIX I: SENSITIVITY ANALYSIS - SCENARIO 3

Scenario 3A (56 kW PV And 50 kWh Storage), with Different IRR and Return on Investment Rate

Return on Investment	IRR	NPV (£)
4.5 %	4.5%	56,578
5%	5%	56,724
5.5%	5.5%	56,736
6%	6%	56,856
6.5%	6.5%	56,956

Scenario 3A (70 kW PV And 50 kWh Storage), with Different IRR and Return on Investment Rate

Return on Investment	IRR	NPV (£)
4.5 %	4.5%	£36,803
5%	5%	£38,356
5.5%	5.5%	£38,954
6%	6%	£38,982
6.5%	6.5%	£38,990

APPENDIX J: LIST OF PUBLICATION

Journal Paper

1. The Impact of Policy Changes: The Opportunities of Community Renewable Energy Projects in the UK and the Barriers they Face
Mirzania, P and Ford, A and Andrews, D and Maidment, G , Energy Policy (under review)

Conference Proceeding and Poster

1. Breakthrough without Feed-in-Tariff: Techno-economics assessment of battery storage as potential business case for commercial and community renewable energy projects
Mirzania, P and Ford, A and Andrews, D and Maidment, G (2018) Energy Systems Conference 2018, 19 June 2018- 20 June 2018, London, UK.

2. Community Energy in the UK: The End or the Beginning of a Brighter Future?
Mirzania, P and Ford, A and Andrews, D and Maidment, G (2017) Energy for Society: 1st international conference on Energy Research & Social Science, 05 April 2017 - 07 April 2017, Sitges, Spain. http://researchopen.lsbu.ac.uk/1809/

3. Investigating business models for the UK 's Community Renewable Energy.
Mirzania, P and Farschi, MA and Ford, A and Maidment, G (2016) Energy Systems Conference 2016: 21st Century, 14 June 2016- 15 June 2016, London, UK.