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Renewable energy in Scotland: Extending the transition-periphery dynamics approach

by

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Abstract

Scotland is being transformed as renewable energy resources are being exploited through new developments and infrastructure as part of an energy transition. Scotland has a significant amount of potential onshore and offshore renewable energy available for capture largely located in rural and isolated regions. Some of this potential renewable energy has been developed and contributes to the increasing amount of energy from low carbon sources in the UK, aiding in the UK reaching its greenhouse gas (GHG) emission targets.

This thesis responds to four research questions. The first proposes an analytical framework that incorporates the concept of resource peripheries and processes of peripheralization and centralization in the multilevel perspective (MLP) from the sociotechnical transitions literature. The second discusses the transition dynamics during the renewable energy transition in Scotland that are being shaped by a number of drivers including the shift to community ownership in Scotland and a range of policies, targets, and legislation. The third address the relationship dynamics between cores and peripheries created through processes of peripheralization that include relational, multi-dimensional processes that are also multi-scalar. The fourth discusses the uneven multi-scalar dynamics created as a transition occurs with processes of peripheralization and centralization creating resource peripheries as 'transition-periphery dynamics'. By better understanding these dynamics and relationships during transitions the renewable energy transition can be better informed to deal with possible implications and ensure possible benefits are secured for a more sustainable future.

Keywords: sociotechnical transitions; geography; resource periphery; renewable energy; policy

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Author’s Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Printed Name: _________________________

Signature: _________________________

Abbreviations

AC	Alternating Current
BETTA	British Electricity Trading and Transmission Arrangements
CARES	Community and Renewable Energy Scheme
CCGT	Combined Cycle Gas Turbine
CES	Community Energy Scotland
CfD	Contracts for Difference
DC	Direct Current
DECC	Department of Energy & Climate Change
EMEC	European Marine Energy Centre
EMR	Electricity Market Reform
EU	European Union
FIT	Feed-In-Tariff
FOSG	Friends of the Supergrid
ft	Feet
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHW/y	Gigawatt Hours per Annum
GW	Gigawatt
HIE	Highlands and Islands Enterprise
HVDC	High-Voltage Direct Current
ICOE	International Conference on Ocean Energy
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
km	Kilometre
kW	Kilowatt
kWh	Kilowatt hour
LES	Local Energy Scotland
LIMPET	Land Installed Marine Power Energy Transmitter
LTS	Large Technical Systems
m	Meter
mi	Miles
MLP	Multilevel Perspective

MW	Megawatt
NFFO	Non-Fossil Fuels Obligation
NIMBY	Not In My Back-Yard
NINES	Northern Isles New Energy Solutions
NoSHEB	North of Scotland Hydro-Electric Board
NYDC	North Yell Development Council
OFGEM	Office of Gas and Electricity Markets
PV	Photovoltaic
RE	Renewable Energy
RED	Renewable Energy Directive
RO	Renewables Obligation
ROCs	Renewables Obligation Certificates
ROS	Renewables Obligation (Scotland)
SEPA	Scottish Environment Protection Agency
SHET	Scottish Hydro Electric Transmission Ltd
SNP	Scottish National Party
SREF	Shetland Renewable Energy Forum
SSE	Scottish and Southern Energy
STS	Science and Technology Studies
TM	Transition Management
TWh	Terawatt-hour
UK	United Kingdom
USSR	Union of Soviet Socialist Republics
WES	Wave Energy Scotland

Chapter 1.

Introduction

Energy systems are continuously changing and adapting. They are shaped as pressures and influences change over time such as availability, prices, technological innovations, political and social environment. These energy systems are central to everyday life. A major challenge and pressure currently on the energy system is that of reducing Greenhouse Gas (GHG) emissions. This has come about due to the consensus among scientists over anthropogenic climate change that, "warming of the climate system is unequivocal" (IPCC 2013, p.4). This consensus is contributing to calls and policy to reduce GHG emissions, particularly in the energy sector. International agreements and national targets have been set in order to make global commitments and reduce GHG emissions. There are many different possible pathways this transition in the energy sector can take in order to adapt to these new targets and policies, and shape future ones. Whichever pathway this transition follows it is inevitable that it will involve major changes not only to technology and infrastructure but also in society, creating a sociotechnical transition.

Many parts of Scotland are being transformed as renewable energy resources, often located in the rural areas, are being exploited through new developments and infrastructure. These developments are having a range of impacts on communities from economic to social and political. There are complex relationships and interactions between these developments and associated communities as well as broader pressures that are being imposed as a nationally-driven shift to renewable energy is taking place to meet GHG emission targets. These dynamics and relationships need to be better understood in order to inform this transition to deal with possible implications and ensure potential benefits are secured.

This study examines particular typess of dynamics and relationships of a sociotechnical transition. More specifically, the study focuses on the dynamics created through processes of peripheralization and centralization between peripheral areas and cores (often urban centres) as there is a shift towards renewable energy by examining Scotland. A case study approach is used with three cases that represent three parts of the electricity sociotechnical system linking urban and rural areas: production, transmission, and storage. These case study sites vary both in terms of renewable energy source (tidal and hydro), as well as geographically within Scotland. Interviews were conducted in these case study sites along with additional interviews around policy and industry for more contextual information and to frame the case study sites. This study links the literature and debate around sociotechnical transitions with resource peripheries to create a stronger combined approach to understanding the shift to renewable energy.

This introduction begins with a summary of contextual information about the energy industry in Scotland, UK, and Europe. This is followed by a description of the issues and the significance of sociotechnical transitions that this study addresses. Then there is a short summary of the literature relevant to this study. This is followed by a brief outline of this study's research objective and research questions. Then there is a summary of the methods used to address the objectives. Lastly there is an outline of the thesis.

1.1. Context: The Existing Energy System

Over time the energy sector has transformed and gone through many radical changes. Humans have changed their energy sources and energy consumption rates have also changed, increasing as regions economically 'develop'. These transitions include the steam powered industrial revolution in the 18th and 19th centuries, and the early development of windmills. These transitions are sociotechnical which means they are intrinsically social as well as technical.

Changing political paradigms have shaped and transformed the energy industry. For example, the Thatcher government in the UK during the 1980s ended the public ownership of a number of energy networks including electricity and gas through privatization and liberalization. The UK electricity industry was privatized in 1990 and in 1998 the markets were further liberalized (Geels et al. 2015). This involved the independent energy regulator Ofgem (Office of Gas and Electricity Markets) taking charge of many policy issues and government taking a more 'hands-off approach' to increase competition and market-principles within the electricity system (Geels et al. 2015). The aim was to create competition within the energy industry and between energy supply companies in order to create a more efficient system (Foxon et al. 2010). This was considered important because the energy supply and distribution systems have been viewed to be 'natural monopolies' because it is practical and efficient to only have one electrical cable or gas pipeline network (Hammond 2000).

The UK relies on five main energy sources: coal and manufactured fuels, gas, oil, electricity, and bioenergy (and heat). As shown in Table 1, oil is the largest consumed fuel type followed by gas, then electricity, next bioenergy and heat, and lastly coal and manufactured fuels.

Table 1 Consumption of fuel types in the UK in 2013 by million tonnes of oil equivalent (Data Source: DECC 2014c, p.8).

	Industry	Domestic	Transport	Services	Total
Coal & manufactured fuels	2.0	0.7	0.0	0.0	2.8
Gas	8.0	29.6	-	10.3	47.9
Oil	4.4	2.8	52.0	1.2	60.3
Electricity	8.4	9.8	0.4	8.7	27.3
Bioenergy and heat	1.4	0.9	1.1	0.7	4.2
Total	**24.2**	**43.8**	**53.4**	**21.0**	**142.5**

Table 1 also shows that the transport sector uses the largest amount of energy measured by million tonnes of oil equivalent, followed by domestic use, then industry, and lastly services which include agriculture. The energy industries make a significant contribution to the economy in the UK, making up 3.3% of the Gross Domestic Product (GDP) in 2013 (DECC 2014c). However, employment in the UK energy sector has decreased drastically since the 1980s and 1990s largely due to coal mine closures, although employment has slowly increased since 2005 largely in the electricity sector (DECC 2014c). The UK has shifted over time from a net importer of energy in the 1970s, to a net exporter in 1981 due to North Sea oil and gas development, and back to a net importer in 2004 (DECC 2014c). The main sources of current energy imports are from Russia (coal), Norway (crude oil and gas), and the Netherlands (petroleum products). As seen in Figure 1 production of primary fuels has decreased in the UK since 2000 for primary oil, natural gas, and coal, whereas primary electricity production has remained fairly stable. Electricity consumption is expected in the long-term to increase due to increased number of consumer electronics, electrification of transport, and heat from electricity (e.g. electric heat pumps) even though overall electricity use in the UK has levelled off (Geels et al. 2015).

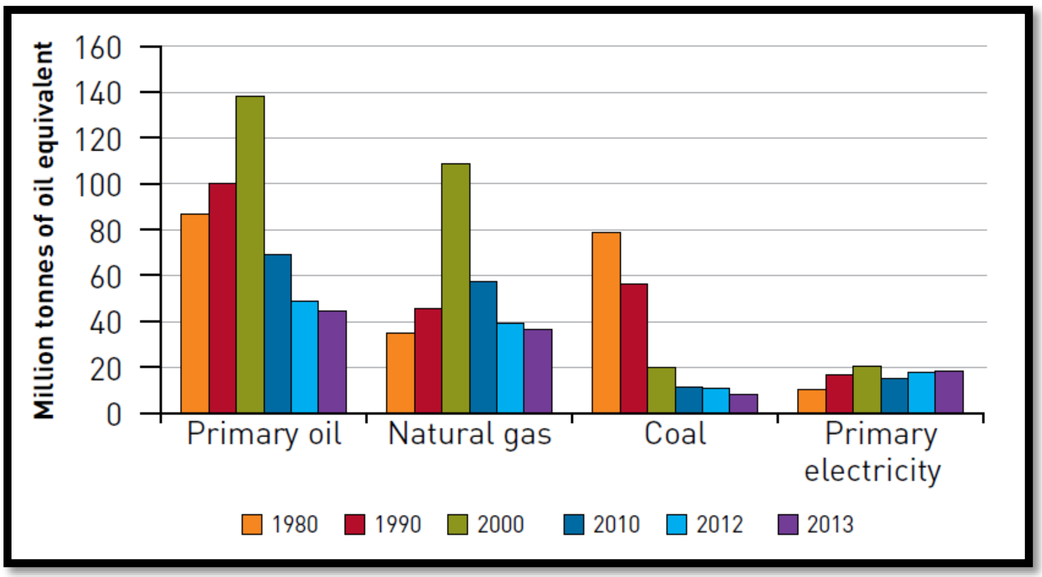

Figure 1 UK primary fuel production from 1980 to 2013 (Source: DECC 2014c, p.6).

The electricity system in the UK involves a highly regulated and infrastructure intensive, centralized national grid system. Figure 2 shows a simplified model of this system in the UK. Energy is initially mined/refined or captured in order to generate electricity, and then is distributed to consumers for end uses. It is important to note that during each stage energy is inevitably 'lost' such as through resistance of transmission cables. During electric power transmission and distribution the UK loses 8% of its output (in 2011) (The World Bank 2014). Within this Figure 2 renewable energies such as wind, solar, and tidal, are considered to be within the 'Hydro/Renewables' category at the bottom of the diagram which are also in a sense 'mined' or 'captured' from the environment. Electricity production in the UK is primarily from coal, natural gas, nuclear power, and a small amount of renewable such as from wind (DECC 2014c). The baseload[1] electricity includes nuclear, coal, gas, biomass, geothermal, and hydro while the dispatchable[2] electricity is sourced from coal, gas, hydro, oil, geothermal, and biomass. This energy is centrally generated and then transmitted and distributed to homes and businesses. The overall efficiency of this system, from electricity production to the supply for the final consumer, has remained relatively constant from the mid-1960s, varying by only 2% (Hammond 2000). However there has been changes for rural areas and cities as Calvert (2015) describes, "the deployment of distributed renewable energy systems is transforming urban areas from spaces of energy consumption into spaces of energy production" (Calvert 2015, p.12).

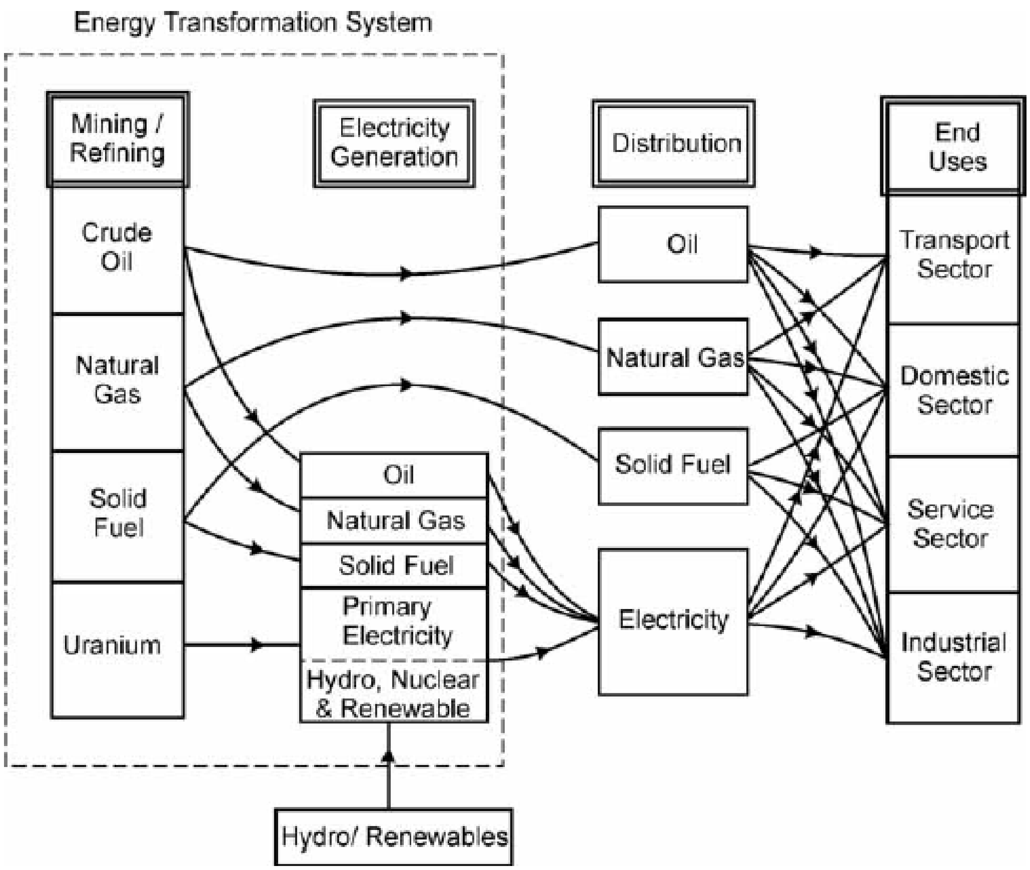

Figure 2 Diagram of the energy flow from production to consumption (Source: Hammond 2000, p.308).

[1] Baseload is electricity that is produced at a constant rate and whose power output is not quickly adjustable as compared to dispatchable electricity sources (e.g. nuclear power stations).

[2] Dispatchable is electricity sources that can be generated at varying power outputs. For example at times of high electricity demand these sources can be adjusted to increase or decrease output relatively quickly (e.g. hydro electricity).

The UK has a wholesale electricity market that was created between electricity generators and suppliers through The British Electricity Trading and Transmission Arrangements (BETTA). BETTA came into effect in April 2005, covering England, Scotland, Wales, and Northern Ireland. BETTA is a market trading system where parties are able to trade off energy imbalances close to real time. The purpose of this system is to promote competition and efficiency, delivering sufficient capacity for consumers from a large, single-price energy market and linked high-voltage transmission system. Scotland's system is run by Scottish Power, and Scottish and Southern Electricity (SSE) which is connected by the England/Scotland interconnectors. The electricity supply industry in the UK is currently dominated by a number of large power producers that are connected to the national, high voltage transmission network that distributes electricity to communities. These distribution systems become weaker the farther they distribute power and vulnerable as they traverse greater distances. Communities rely on this electricity to power lights, various appliances (fridges, freezers, kettles, computers, phones, etc.), and heating in some cases. The transmission infrastructure is aging and requires upgrades and reinforcement. Much of Scotland's transmission network was built after world war two during the electrification of Scotland.

The 'dash for gas' in the 1990s and high gas prices increasing in the early 2000s have resulted in a need for diversification away from over-reliance on gas. This has contributed to coal remaining a significant contributor to electricity generation in the UK even though it produces a relatively large amount of Greenhouse Gas (GHG) emissions for each unit of electricity produced (DECC 2014c). Coal-generated electricity made up 22.6% of the electricity generated in the UK in 2015 (DECC 2016). Carbon capture and storage is argued to be a useful way to offset the carbon emitted from coal by storing emitted carbon underground. Coal use for electricity generation has gradually decreased since its peak in 2006 (DECC 2014c). Coal production in the UK has been steadily decreasing, falling to 13 million tonnes in 2013 (DECC 2014c). A number of UK mines with deep mine production closed in 2013 (Maltby, Daw Mill, and Unity) along with a surface mining company (Scottish Coal Company) liquidated. To compensate for this decrease in production coal imports began in 1970 growing to exceed UK production for the first time in 2001. These imports peaked in 2006 at 51 million tonnes (75% of total

UK coal supply) to largely decrease since then with a small increase since 2011 due to changing demands from electricity generators (DECC 2014c).

Oil and gas production in the UK is declining (DECC 2014c). In the past the UK has been self-sufficient in petroleum supplies such as in 1981 after developing its North Sea oil during the 1970s and 1980s, however this is no longer the case (Hammond 2000). The UK Continental Shelf reserves are also depleting, with gas production down by 6% between 2012 and 2013, which is 66% lower than the 2000 record production levels (DECC 2014c). There is uncertainty as to the size of the remaining fossil fuel reserves which are often considered 'finite' (Hammond 2000). However the perceived level of 'finiteness' of fossil fuels is continuously changing as new reserves are uncovered such as through fracking; the extraction of gas from shale rock.

Natural gas consumption in the UK grew, along with natural gas production, from the early 1970s until its peak in 2004 (at 1,125 TWh) (DECC 2014c). Since the 2004 peak, consumption has declined by roughly 25% as of 2013 (DECC 2014c). Gas-generated electricity made up 29.6% of the electricity generated in the UK in 2015 (DECC 2016). The production of natural gas in the UK has also been declining since its peak in 2000. To compensate for this production decline net imports have increased to 50% of the UK natural gas demand (DECC 2014c). These imports largely come from the diverse pipeline infrastructure the UK shares with Belgium, the Netherlands, and Norway. Natural gas is being framed by some such as the Intergovernmental Panel on Climate Change (IPCC) as a 'bridging fuel' as part of the transition to renewable energy sources (IPCC 2007). Stephenson et al. (2012) describes how this approach to natural gas is part of the 'climate solution' based on the argument that, "natural gas is relatively inexpensive, burns cleaner and more efficiently than coal or oil, and is a leading option for backing up intermittent renewable sources with easily dispatchable, scalable generators" (p.452). However this has been questioned as problematic due to its contested production impacts (Stephenson et al. 2012). The UK is exploring fracking to determine the potential in the UK (DECC 2012). Fracking is controversial because of environmental impacts and pollution risks. Geels (2014) argues that since 2013 for fracking, "the government pushed ahead, dismissing opponents as uninformed NIMBY-activists ('not in my back-yard'), and attempting to 'bribe' local authorities by promising them 1 per cent of revenues" (Geels 2014, p.35).[3] Supporters view fracking as a step forward in developing a more secure energy source for the UK.

Commercial nuclear power plants were first constructed in the 1950s (Pocock 1977). Nuclear generated electricity made up 20.8% of the electricity generated in the UK in 2015 (DECC 2016). There are public concerns over the safety of nuclear power which has been reinforced by events such as Chernobyl (USSR/Ukraine) in 1986 and more recently Fukushima (Japan) in 2011. A disadvantage to nuclear power is the radioactive waste that is produced and its disposal. The initial capital costs are also relatively high for nuclear power as well as with decommissioning of the plants which have limited life-spans (typically a design life of 25 years and often extended to nearer 40 years) (Hammond 2000). Nuclear power plants have a high energy density in that they produce large amounts of energy relative to the amount of space the plants require. Nuclear power is often considered a low carbon energy source however, it is not generally classified as renewable because the most common nuclear fuel source, uranium, does not regenerate indefinitely. The further deployment of nuclear energy is highly dependent on public opinion because of the concerns over safety (Hammond 2000). Government also plays an important role as they create policies and support mechanisms. In Scotland the Scottish National Party (SNP) is against the construction of any new nuclear power plants. In England there is support for new nuclear power stations as shown by the development of the Hinkley Point C Nuclear Power Station (3.2GW[4]).

Hydroelectric power has been widely deployed in Scotland. There was some private development of hydro power in the 1920s to support the aluminium smelting industry (Payne 1988). However there was a large expansion during the post-war years (1940s-1950s) in an effort to create economic development and social support (Munro & Ross 2011). Between 1950 to 1965, 74 hydropower installations were constructed, which totalled over 950MW of installed capacity (Nelson 2013). This was in part due to efforts

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[3] The concept of NIMBY has been criticized by academics for being overly simplistic and as being used to discredit local residents' objections (Devine-Wright 2011b).

[4] 3.2GW is equivalent to roughly 7% of Britain's electricity demand (UK Government 2016).

by the North of Scotland Hydro-Electric Board (NoSHEB) which was established under the Hydro-Electric Development (Scotland) Act 1943. This expansion was met with a certain amount of protest and debate between those wishing to protect the ‘natural’ state of the region as opposed to the ‘public good’ argument for economic development in areas in decline (Munro & Ross 2011). This period of hydropower development ended as there were fewer suitable and economical sites for development along with other energy generation technologies such as conventional thermal and nuclear power became more cost-effective and efficient (Payne 1988). These large historic, conventional hydro schemes make up the majority of current Scottish hydropower (Nelson 2013). Britain’s electricity industry was privatized in the 1990s (Institution of Mechanical Engineers 2012). Scottish and Southern Energy (SSE) took ownership of much of the NoSHEB’s hydro power at this time of privatization (Nelson 2013). Hydro-generated electricity made up 1.9% of the electricity generated in the UK in 2015 (DECC 2016). The most favourable sites for large-sale hydropower and pumped storage schemes have already been developed and those that have not tend to be located in National Scenic Areas and National Parks, therefore in the UK further development is limited (Hammond 2000).

The UK energy system is complex as it relies on a number of different energy sources. Each energy source has a range of implications with respect to economic viability, security, and environmental and social impact. As oil and gas prices rise and problems with international gas supplies emerge, energy security and affordability are issues that have come to the forefront (Geels 2014). These concerns are shifting the focus from renewable energy as the solution to climate change as seen in the 2003 White Paper, Our Energy Future: Creating a Low-Carbon Economy. Geels (2014) argues this shift in focus has benefitted existing energy regimes rather than alternatives,

> The 2003 White Paper portrayed climate change as the central problem and renewable energy as the main solution. Since about 2005, however, energy security and affordability (low costs) have been emphasized as additional, and perhaps even more important, problems. These changes were partly related to rising oil and gas prices ... and Russian gas supply problems (related to a 2005 conflict between Russia and Ukraine), but also benefitted existing regimes. (Geels 2014, p.30)

The issue of energy ‘affordability’ has been an issue prior to 2005 with the discussion around the term ‘fuel poverty’ since 1997 by official Government policy (Boardman 2004). Existing energy regimes have benefited because industries such as coal have repositioned themselves as being able to deliver energy affordability and security while also promising carbon capture and storage development to decrease GHG emissions (Geels 2014). Nuclear power, along with natural gas and shale gas, have also repositioned themselves as low carbon energy, the answer to climate change and energy security (Geels 2014). Geels (2014) argues that this, “resistance and resilience of coal, gas and nuclear production regimes currently negates the benefits from increasing renewable deployment” (p.21) and that, “policymakers and many transition-scholars have too high hopes that ‘green’ innovation will be sufficient to bring about low-carbon transitions” (p.21). These energy industries will continue to adapt in order to resist being replaced.

Scotland’s energy is governed by a multi-level governance structure with the main levels being the European Union (EU), UK, and Scotland. The UK is a member of the EU however, as a result of a referrendum the UK is negotiating its depearture from the EU. The EU holds powers to set binding targets for members. For example the EU’s 2009 Renewables Directive (2009/28/EC) set a binding target of 20% share of energy from renewable sources by 2020. The EU also has set longer term targets to 2030 and 2050 with associated roadmap documents to accompany these targets (Energy Roadmap 2050). The UK Parliament reserves the power to make laws around energy. A range of powers such as local government, environment, and tourism, have been transferred from the UK Parliament through devolution to the Scottish Parlaimant since its creation by the Scotland Act 1998. Scotland’s devolved powers were further extended by the Scotland Act 2012. Energy policy is a reserved power specifically for the UK Parliament as part of the Scotland Act 1998. However, Scotland is able to influence the energy sector through policies that can set targets, such as the 2020 Routemap for Renewable Energy Scotland (2013a) (an updated extension from the Scotland Renewables Action Plan (2009)), that sets a target for 2020 of equivalent of 100% of electricity demand in Scotland to be from renewable sources. The Scottish Government holds the powers to approve and refuse planning applications for new energy developments (Dalglish et al. 2017).

1.2. Problem and Significance

Atmospheric GHG levels will increase if the billions of tonnes of annual GHG emissions continue. The expected outcome is in climate change that will result in sea level rise, ocean acidification, precipitation pattern change, Earth’s average temperature increase, and reduce snow and ice cover. Average global temperature is predicted by the IPCC’s Fifth Assessment Report to increase by 0.3°C to 4.8°C by 2100 depending on future GHG emission levels and the climate model (IPCC 2013). The UK is one of the countries working to decrease its GHG emissions through targets. These targets include a GHG emission reduction of 34% by 2020 and a further 80% by 2050 based on 1990 levels as set out in the UK Climate Change Act (2008) (DECC 2009b). This UK Act positioned the UK as the first country in the world to have a legally binding framework to cut carbon emissions (Hodson et al. 2015).

The UK has decreased its GHG emissions since 1990 as shown in Figure 3. The UK has reduced its GHG emissions by 33% between 1990 and 2014 (Committee on Climate Change 2016). It is estimated that 2013 emission levels of the six gases included in the Kyoto Protocol (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorinated chemicals, and sulphur hexafluoride) were 1.9% lower in 2013 as compared to 2012 in the UK (DECC 2014c). These 2013 emission levels at 569.9 million tonnes of carbon dioxide equivalent are 27% lower than emission levels in 1990 (777.6 million tonnes) (DECC 2014c). However with these measures it is important to note that emissions are being off-shored by countries through importing goods that involve large GHG emissions and pollutants to produce. GHG emissions are currently widely measured by where they are released into the atmosphere rather than as embodied within products. Research is beginning to examine how to calculate this embodied energy in international imports and exports, such as by Tang et al. (2013) who found that the UK is a net embodied fossil energy importer since 1997, at levels less than direct energy imports, but still significant. Barrett et al. (2013) argue that a consumption-based emissions measure would be more appropriate particularly for policies.

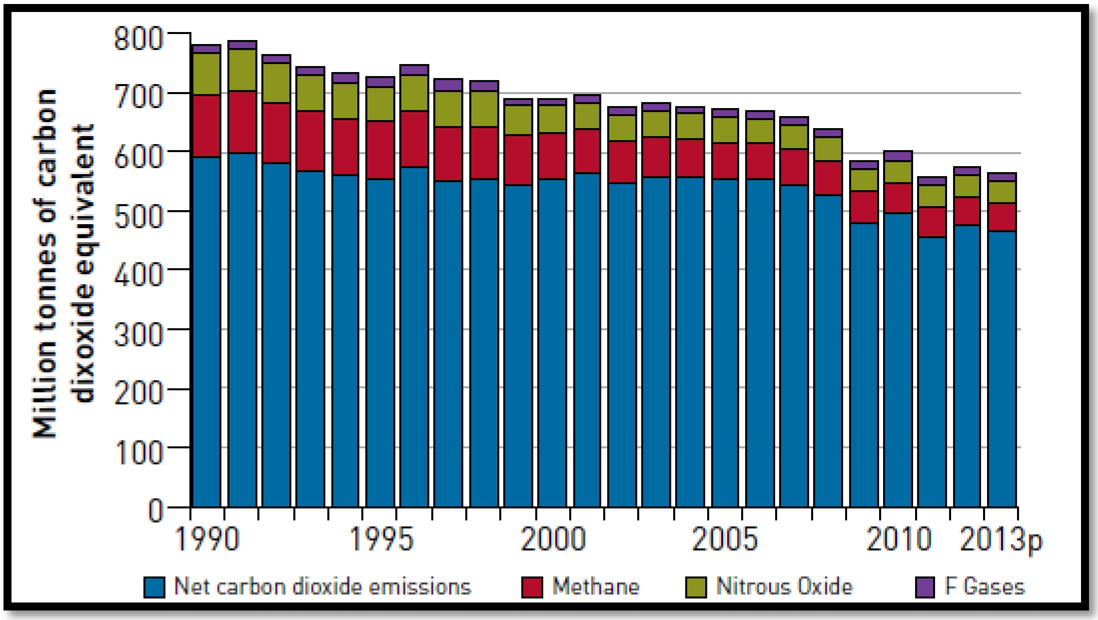

Figure 3 Greenhouse gas emissions by gas in the UK from 1990 to 2013 (Source: DECC 2014c, p.13).

The renewable energy sector has developed and expanded in the UK and this has contributed to the decarbonisation of the energy industry and GHG emission targets. This expansion has been made possible through mechanisms and policy instruments such as the Renewables Obligation (RO) (a tradable certificates scheme) (DECC 2009a) and the Feed-In-Tariffs (FITs) (contract pricing scheme favouring renewable energy sources) (DECC 2015). These initiatives have resulted in an increase in low carbon energy sources such as wind and bioenergy being utilized in the UK as shown in Table 2. Nearly 13% of the UK's primary energy came from low carbon sources in 2013, of which nuclear power contributes a significant portion of just under 60% (DECC 2014c). Renewable-generated electricity has grown to 24.7% of the electricity generated in the UK in 2015 (DECC 2016). For Scottish gross electricity 59% of consumption was met by renewably sourced electricity in 2015 (Scottish Government 2017b). This shift in energy production to low carbon sources will transform the production, consumption, and governance of energy, and suggests reconfiguration of the current sociotechnical system (Murphy & Smith 2013; Rip & Kemp 1998).

Table 2 Percentage of primary energy in the UK in 2013 from low carbon sources (Data Source: DECC 2014c, p.11).

	2000	2009	2010	2011	2012	2013
Nuclear	8.4%	7.2%	6.4%	7.7%	7.3%	7.5%
Wind	0.0%	0.4%	0.4%	0.7%	0.8%	1.2%
Hydro	0.2%	0.2%	0.1%	0.2%	0.2%	0.2%
Bioenergy	0.9%	2.1%	2.3%	2.6%	2.8%	3.3%
Transport fuels	0.0%	0.5%	0.6%	0.6%	0.5%	0.5%
Other	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%
Total	**9.4%**	**10.4%**	**9.8%**	**11.9%**	**11.8%**	**12.9%**

Scotland has a large amount of potential onshore and offshore wind, wave, tidal current, biomass, solar energy, and geothermal energy available for capture largely located in rural regions (Bergmann & Hanley 2012; Toke et al. 2013). Some of this potential renewable energy has been developed and contribute to the increasing amount of energy from low carbon sources in the UK, aiding in the UK reaching its GHG emission targets. Scotland has reduced its GHG emissions by 39.5% between 1990 and 2014 (compared to the UK with 33% reduction) (Committee on Climate Change 2016). However, the development and exploitation of renewable energy in many parts of Scotland are having a range of impacts for communities as these areas are transformed by these developments. Complex relationships and interactions exist between these developments and associated communities. Large amounts of infrastructure linked with these developments are required to transfer this newly captured energy from the rural areas where it can be generated, to cores where the energy is consumed. Since renewable energy is primarily located in rural regions, different areas than where current energy is largely produced, a ‘re-wiring of Scotland’ is taking place. For example, the Beauly-Denny power line upgrade is currently under construction, a 600-pylon network of 220km (137mi), to increase capacity to transfer renewable power from the Highlands to central Scotland. It is argued that further interconnectors and infrastructure upgrades will be required in other regions of Scotland, such as the Outer Hebrides, in order for further renewable energy development to occur.

There are broad pressures being imposed on rural areas, where renewable energy is generally located and captured, as a nationally-driven shift to renewable energy is taking place. It is these dynamics and relationships that deserve attention and need to be better understood in order to better deal with possible implications and best secure possible benefits of renewable energy.

1.3. Prior Research

This study brings together two bodies of literature: that of sociotechnical transitions and resource peripheries. These areas of study have remained relatively separate. The term sociotechnical transition refers to the shift from the use of one technology to another by a society that involves a transformation in society through infrastructure, knowledge, and ways of life. This work stems from the sub-disciplines of sociology of technology and innovation studies (Geels 2002). The earliest literature in this area was on technological transitions or shifts and began in the 1990s (Kemp 1994; Kemp et al. 1998; Rip & Kemp 1998; Schot et al. 1994; Schot & Rip 1996). Interest has grown and a shift was made to the use of the term sociotechnical transition since the 2000s (Elzen et al. 2004; Geels 2002; Geels & Schot 2007; Murphy & Smith 2013; Rotmans et al. 2001; Scrase & Smith 2009; Turnheim & Geels 2012). This research takes a systems and evolutionary perspective to examine various sociotechnical systems such as food, water, transport, technology, and energy. A focus in this literature has been on radical innovation emergence (niches) rather than other aspects of transitions such as the destabilisation of existing regimes (Turnheim & Geels 2012). Historical case studies have also been favoured as they are generally completed events that have the advantage of being able to be examined in their entirety (Turnheim & Geels 2012). There are two main approaches within the sociotechnical transitions literature: the multilevel perspective (MLP) and transition management (TM). TM examines how transitions can be managed through strategies for public decision-makers and private actors with a more process-oriented approach (Rotmans et al. 2001). The TM approach, “subscribe to models of agency and intervention” in that the, “main point is that very idea of transition management supposes that deliberate intervention in pursuit of specific goals, like those of sustainability, is possible and potentially effective”(Shove & Walker 2007, p.764). However, the level to which transitions can be ‘managed’ is debatable and therefore this study does not adopt the TM approach.

This research utilizes the multilevel perspective (MLP) which is one of the main approaches to understanding sociotechnical transitions (Geels 2002; Genus & Coles 2008; Markard & Truffer 2008; Rip & Kemp 1998; Smith & Stirling 2010). In the MLP approach there are three levels of a sociotechnical transition: niche (micro level), regime (meso level), and landscape (macro level). Niches protect and nurture radical innovations from the regime (Geels 2010). Regimes are the dominant practices, rules, and shared assumptions that guide activities within communities (Rotmans et al. 2001). Landscape is the context and external factors in which interactions and changes take place (Geels 2002). Actors and organisational networks are embedded within the sociotechnical system, in the landscape context and their perceptions and actions are guided by the regime and rules (Genus & Coles 2008). The three levels have a nested character with niches embedded within regimes, and regimes within landscapes (Geels 2002). A sociotechnical transition is the change from one sociotechnical regime to another (Geels & Schot 2007). The transition is the product of developments within and between the three levels that create new alignments (Geels & Schot 2007). Transitions have a range of possible pathways in terms of direction, scale, and speed (Rotmans et al. 2001).

The MLP is often treated as a global (macro) model to understand the entire transition process; however it can also be applied to other scales (Geels & Schot 2007). The dynamics at the local level, niche dynamics, can be examined through case studies (Geels & Schot 2007). However, the literature has emphasized large-scale, long-term change rather than local-scale, unique processes and outcomes (Murphy & Smith 2013). A challenging aspect of the MLP is that it is difficult to create boundaries with the analysis of regimes due to their broad and overlapping nature (Geels 2002). Suggestions have also been made such as to focus more on power and politics involved in developing policy as well as ‘multi-level governance’ (Geels 2014; Hodson & Marvin 2009). The sociotechnical transitions literature and MLP approach are discussed in more depth in Chapter 2 Sociotechnical Transitions.

The influence and importance of geography has been neglected by sociotechnical transition research until relatively recently (Coenen et al. 2012; Lawhon & Murphy 2011; Murphy 2015; Hansen & Coenen 2015). In the past focus has been on the temporal aspects of transition ('causality of time') rather than on the geography of space and time (Bridge et al. 2013; Coenen et al. 2012; Hacking & Eames 2012). Including considerations of geography is important because it allows for better understandings of why, where, and when transitions occur unevenly across space (Lawhon & Murphy 2011). Over the past few years there has been an emerging interest in incorporating and understanding the geographical dimension of transition processes (Markard et al. 2012; Smith et al. 2010; Chandrashekeran 2016). Spatial context should play a larger role in identifying and being a part of theory and causal explanation (Coenen et al. 2012). The literature has identified that more research is needed, particularly using case study analyses, to address this gap in the sociotechnical transition literature to incorporate geography which is what this study addresses (Hacking & Eames 2012).

Resource periphery is a concept that has been implicitly and explicitly applied to a range of settings (Murphy & Smith 2013). It is linked to world systems theory and dependency theory. Resource peripheries are part of core-periphery relationships. Friedmann (1966) developed theory with respect to the processes of development which cause cores and peripheries to be created. Cores are areas that have developed faster than peripheries and tend to exploit peripheries. Core-periphery theory has been frequently applied to both international relations to explain why certain countries have developed relatively faster than others, and to resource-based communities that tend to be exploited to supply cores with resources (Smith and Steel 1995). It has also been used to explain the process whereby urban centres become to dominate decision making for rural resource-based communities (Smith and Steel 1995). It has been suggested that resource peripheries are more deeply contested than cores because of economic geography issues in resource peripheries that are due to resource production, including extraction with minimal processing, occurring within the local area before export (Hayter et al. 2003). Past research has focused on cores rather than peripheries particularly within economic geography (Hayter et al. 2003). This focus has created a need for further research on peripheries which has been noted in the literature (Murphy & Smith 2013).

Related literature and debate has emerged around various forms of resource seizures. A new form of legitimization used to justify land and resource appropriation is the new global green agenda (Fairhead et al. 2012). In these cases the concerns for the livelihoods of the rural people are outweighed by the green agenda and the elites/firms who will profit. This green agenda can be expressed in various ways such as through national targets or certification requirements. The concept of ‘green grabbing’ has emerged in the literature and refers to land and resource appropriation for environmental reasons (Fairhead et al. 2012). Appropriation can be in the form of changes to access, management, or use through rules and authority alterations that can cause alienating impacts (Fairhead et al. 2012). Increasingly nature is being commodified and appropriated by a large range of actors (Fairhead et al. 2012). People who live in resource peripheries are vulnerable because of the potential for their resources and lands to be appropriated for economic, larger scale ‘greater good’, and environmental justifications (Fairhead et al. 2012). However, there are alternative types of developments to the more traditional large-scale, private resource extraction projects. These have taken many different forms, for example in Scotland some of these local initiatives have taken the form of community land buyouts and then in some cases resource development of the community-owned land (Mackenzie 2006b; Mackenzie 2006a). This community-ownership results in direct management by the community of the land and resource that allows control for different forms of development to occur. These concepts and literature around resource peripheries are discussed in more depth in Chapter 3 Resource Peripheries.

As stated earlier the literature on the sociotechnical transitions approach has tended to neglect geographical influences (Coenen et al. 2012; Lawhon & Murphy 2011). Murphy and Smith (2013) suggest that this lack of consideration for geography in the sociotechnical transitions approach can be aided by being combined with the concept of resource peripheries. How can the approaches of sociotechnical transitions and core-peripheries be linked? Murphy and Smith (2013) connect and extend these concepts of sociotechnical transitions and resource peripheries by providing an application of the concepts to wind energy projects on the Isle of Lewis in Scotland. The approaches of sociotechnical transitions and resource geographies are quite different but complementary to each other. Each of these perspectives can contribute to the other, creating a stronger overall approach when combined. Resource peripheries are centered on geography because resource extraction occurs in a specific place and focuses on relations and dynamics between peripheries and cores. The sociotechnical transitions approach is focused on the overall transition that occurs from one sociotechnical regime to another. Therefore by bringing the two approaches together, a focus can be directed to the geographical relationship dynamics present during a sociotechnical transition. The processes that occur in resource peripheries during sociotechnical transitions can be characterized by highly complex transition-periphery dynamics. Therefore, this combined approach of sociotechnical transitions and core-periphery dynamics is particularly useful for understanding new resource peripheries and associated sociotechnical transitions.

1.4. Objectives/Research Questions

The overarching aim of this study is to enhance understandings around the geographical aspects of sociotechnical transitions. More specifically, the study focuses on the core-periphery dynamics of the transition towards renewable energy taking place in Scotland. To address this objective there are a set of research questions:

1. How can the multilevel perspective (MLP) on sociotechnical transitions be incorporated with the concept of resource periphery to create a more **geographically sensitive model** for understanding new resource peripheries?

2. What are the **sociotechnical transition dynamics** during a sociotechnical transition?

3. What are the **core-periphery dynamics** during a sociotechnical transition?

4. How are **sociotechnical transition dynamics** interlinked with **core-periphery dynamics** in the case of Scotland’s transition to renewable electricity?

Each of these research questions are addressed in this study. Chapter 4 Analytical Framework addresses the first research question. The second, third, and fourth research questions are addressed in the Chapter 10 Analysis and Chapter 11 Discussion.

1.5. Approach

In order to address the overall objective of this study that examines the geographical dynamics of a renewable energy sociotechnical transition, I collected data through a collective case study approach with three cases. An inductive and normative approach was used as is common in this research area (Shove & Walker 2007; Smith et al. 2010).[5] An initial literature review was conducted on sociotechnical transitions and resource peripheries in order to contextualize the study in the literature. The focus of this study is on Scotland, however, in order to include the various influences and systems involved, the unit of analysis includes differing levels of jurisdiction including the EU, UK, and Scotland governing authorities as well as the UK market and infrastructure. The case study approach was used in combination with semi-structured interviews because of the ability of these methods to offer explanatory data that can contribute to subsequent generalizations. The case study approach has also been widely used in past research in both the fields of sociotechnical transitions (Foxon et al. 2010; Geels 2002; Murphy & Smith 2013; Smith 2007; Solomon & Krishna 2011; Turnheim & Geels 2012) and core-periphery dynamics (Borras et al. 2012; Edwards 2011; Leach et al. 2012; Murphy & Smith 2013).

The case study method allows for a holistic, in-depth investigation of the nature and complexity of a particular case (Stake 1995). The type of case study utilized in this study is Collective, as defined by Stake (1995) because there is a group of three cases. By using multiple cases there is an increase in the explanatory power and thus generalisability from the collected data (Miles & Huberman 1994). This study's case study can also be considered Instrumental because the purpose of these cases is to create understandings beyond the cases themselves which is to understand the wider phenomenon of the sociotechnical transition to renewable energy (Stake 1995). The case study selection process used purposive sampling of part of Scotland's electricity system. The selection of these case study sites was based on having cases for three parts of the

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[5] An inductive approach, also called the 'bottom up' approach, works from specific observations where patterns are identified, that then build to broader generalizations and theories. The normative approach makes statements about the way things should be.

electricity sociotechnical system: production, transmission, and storage. The selection of cases was aided by a three week scoping trip I conducted within peripheral Scotland during June and July of 2014. The purpose of the scoping trip was for reconnaissance to collect preliminary information to aid in case study site selection and understand the local geographic context for the study. No formal data collection took place during the scoping trip. The trip covered the peripheral generation of renewable energy and the associated transmission in Scotland. The route of the scoping trip was based on selecting a variety of locations that were of particular interest relating to renewable energy.

Semi-structured interviews were the main form of data collection and were used within the case study sites. Additional semi-structured interviews were conducted to give landscape and regime level (MLP levels) context to the case study sites from various parts of the electricity system. Semi-structured interviews were chosen for this study because of their flexible nature. Interviews were with actors who can be considered key informants such as industry experts, renewable energy policy makers, and decision makers. Interviewees were selected based on Marshall's (1996) criteria: their role within the community, knowledge base, willingness to cooperate/participate, good communication skills, level of bias and objectivity. A total of 22 interviews were conducted as well as observation notes taken during the time I spent at each site. An interview protocol was developed as a flexible guide for these interviews that included a set of open-ended questions that were predetermined and address the study's objective and research questions. During interviews there were additional questions to the predetermined questions that emerged from the interviewer and interviewee dialogue (DiCicco-Bloom & Crabtree 2006). This data was collected after ethics approval was obtained from the University of Glasgow's College of Social Sciences Research Ethics Committee. The recordings from the interviews were transcribed and analyzed for common themes through identification of key phrases, ideas, and concepts (Krueger & Casey 1994). To aid in this data analysis the software program NVivo was used. Findings from the study were made available to the interviewee participants and communities if requested when the study was completed. A more detailed description of the methods of this study is provided in Chapter 5 Methods.

1.6. Outline of the Thesis

This thesis consists of twelve chapters beginning with this introduction. The next section Chapter 2 Sociotechnical Transitions consists of a summary of the sociotechnical transitions literature. The origins and theories developed in the literature to understand sociotechnical transitions are described with particular focus on the MLP. This is followed by an outline of the research conducted on energy transitions. Lastly this chapter considers the lack of consideration for geography within the sociotechnical literature and theoretical approach, and the attempts thus far to incorporate geography.

Chapter 3 Resource Peripheries summarizes the literature on resource peripheries. In particular it examines research conducted on core-periphery relationships. This is followed by a general look at the understanding of nature and resources in the rural context. This leads into a summary of the literature on the concept of green grabbing, where environmental justifications rationalize resource seizures. The literature on community land buyouts is then described as it is an alternative to mainstream, large-scale resource developments.

Chapter 4 Towards an Analytical Framework presents an analytical framework for the study based on bringing together the previous chapter on sociotechnical transitions (Chapter 2) and the chapter on resource peripheries (Chapter 3). This chapter addresses the first of this study's research questions. A combined approach of the concepts of sociotechnical transitions and core-periphery dynamics is proposed as a highly useful approach in better understanding resource periphery development and associated sociotechnical transitions.

Chapter 5 Methods outlines the methods utilized in this study. There is a description of the objective and the research questions are listed. The reasoning behind the use of the case study method is explained as well as the use of semi-structured interviews. The case study selection process is then outlined. This is followed by a detailed description of the analysis methods. There is then a brief discussion of the limitations of this study.

Chapter 6 General renewable energy gives a broad context for this study by summarizing recent developments around renewable energy technology and policy in the context of Scotland. The chapter is structured around the MLP framework by organizing it into the three levels: (1) landscape, (2) regime, and (3) niche. This is followed by a discussion of the general implications of renewable energy development in Scotland.

Chapter 7, 8, and 9 details the three case study sites: North Yell Tidal Scheme, Shetland Interconnector, and Coire Glas (and Cruachan). These chapters include descriptions of the relevant histories of the case study sites and renewable energy developments. Also, relevant policy information and a selection of quotes from the interviews are discussed.

Chapter 10 Analysis describes the analysis and findings from this study. It begins with an analysis of the case study sites in relation to the analytical framework. The remainder of the chapter is organized around the key themes identified from the analysis: transition dynamics, core-periphery dynamics, and transition-periphery dynamics. These key themes are also associated with the second, third, and fourth research questions of this study.

Chapter 11 Discussion details the interpretations from the study's findings and is organized around the same three themes from the previous Chapter 10 Analysis. The transition dynamics section examines the political qualities of technology and also employs the concepts of path dependency and lock-in to discuss the study's results. The core-periphery dynamics section is structured around and utilizes the concepts of resource making and green grabbing (concepts examined in more detail in Chapter 3 Resource Peripheries). The transition-periphery dynamics section discusses resource development, the role of infrastructure, and the future in terms of what the renewable energy transition is moving towards.

Chapter 12 Conclusion discusses and answers each of the research questions in turn. The theoretical and policy implications of the findings are described. This includes a number of policy recommendations. There is also a brief discussion of the limitations of the study. Recommendations for further research are presented. The chapter concludes with a brief wider discussion of cases from other parts of the world from that of this study’s focus of Scotland.

Chapter 2.

Sociotechnical Transitions

This chapter presents a literature review of the sociotechnical transitions literature relating to this study. This is the first of two literature review chapters. The chapter begins by discussing the fields of Science and Technology Studies (STS) and innovation studies. These fields are important because sociotechnical transitions literature stems from sociology of technology and innovation studies (Geels 2002). The sociotechnical transitions literature is then discussed. This is followed by a summary of the literature that focuses specifically on energy related sociotechnical transitions. The next section considers the role of geography and how much consideration it has been given within the fields of STS and innovation studies as well as within transition studies. The limited amount of literature that examines the geographical aspects of sociotechnical transitions is described. This study aims to contribute to this limited area of study by furthering the theory and understandings around geographical aspects of sociotechnical transitions.

2.1. Science, Technology, and Innovation Studies

Science and Technology Studies (STS)[6] and innovation studies are fields of study that have both contributed to the sociotechnical transitions concepts and literature (Hansen & Coenen 2015; Hansen & Coenen 2013). These fields have different approaches and focuses with various strengths and weaknesses. STS focus on the social aspects of technology in that both are shaped by one another. Innovation studies tend to emphasize innovation and the processes of knowledge generation to commercialization of technology.

[6]STS is also considered to stand for Science, Technology and Society however it is the same research area as Science and Technology Studies (Winner 1995).

2.1.1. Science and Technology Studies (STS)

Science and Technology Studies (STS), also known as Science, Technology and Society, is an academic field that emerged in the mid-1960s and has grown since then (Jasanoff et al. 1995). STS understands technology as, "never purely technological: it is also social. The social is never purely social: it is also technological" (Bijker & Law 1992, p.305). Technologies are understood as to be inseparable from the social, in that technologies, "only exist by being embedded into the social" (Ellis et al. 2009, p.544). Technologies only evolve or change because they are socially shaped in a certain way, as described by Bijker and Law (1992), and that there is no, "impetus of some necessary inner technological or scientific logic" (p.5). Technology shapes and is shaped by a number of factors,

> Technology does not spring, ab initio, from some disinterested fount of innovation. Rather, it is born of the social, the economic and the technical relations that are already in place. A product of the existing structure of opportunities and constraints, it extends, shapes, reworks, or reproduces that structure in ways that are more or less unpredictable. And, in so doing, it distributes, or redistributes, opportunities and constraints equally or unequally, fairly or unfairly. (Bijker & Law 1992, p.11)

Technology[7] is often perceived in society to be neutral tools and aspects are not considered such as how, "a given device might have been designed and built in such a way that it produces a set of consequences logically and temporally prior to any of its professed uses" (Winner 1995, p.32). However, technologies can have, "encompassed purposes far beyond their immediate use" (Winner 1995, p.32).

2.1.2. Determinism

Two concepts that have been used to explain technology and power are 'social determination of technology' and 'technological determinism'. With social determination of technology, "what matters is not technology itself, but the social or economic system

[7] In this context Winner (1995) uses the term technology as meaning "all of modern practical artifice, but to avoid confusion I prefer to speak of technologies, smaller or larger pieces of systems of hardware of a specific kind" (Winner 1995, p.30).

in which it is embedded" (Winner 1995, p.28). This draws from social constructionism where reality is understood as a social construction in which knowledge is socially and culturally constructed through human interaction (Kim 2001). Technological determinism (as known as technical determinism) is the concept that, "technology develops as the sole result of an internal dynamic, and then, unmediated by any other influence, molds society to fit its patterns" (Winner 1995, p.29). It is also described as where, "technologies change, either because of scientific advance or following a logic of their own; and they then have effects on society" (Mackenzie & Wajcman 1999, p.3). This is a common approach to understanding the relationships between society and technology however it is too narrow. It is also the dominant approach used in newspapers and other mass media (Mackenzie & Wajcman 1999). Mackenzie and Wajcman (1999) argue that technological determinism, "contains a partial truth" (p.3) but that it is more complex. In a response to technological determinism, Pinch and Bijker (2012) argue for the Social Construction of Technology (SCOT) approach where human action shapes technology.

A theory that draws on both social determinism and technological determinism is that of technological momentum, a theory originally developed by Thomas P. Hughes (1983), according to which sociotechnical systems have mass movement and direction. According to the theory there is an initial social determinism to the technological momentum that then shifts over time into a more technological determinism. This is a far more balanced theory in that it recognizes the influences of both social determinism and technological determinism. The relationship between society and technology is complex as this study shows with society shaping technology and technology shaping society.

2.1.3. Systems Perspective

Technologies tend to be part of larger systems. These technologies and technical systems have political qualities and embody certain powers. These systems influence technology design since, "the need for a part to integrate into the whole imposes major constraints on how that part should be designed" (Mackenzie & Wajcman 1999, p.11). The example presented by Mackenzie and Wajcman (1999) was that the light-bulb was not designed, "as an isolated device but as part of a system of electricity generation and distribution, and the needs of the system are clearly to be seen in the design of the bulb" (p.11).

Winner (1995) describes two types of political qualities of technologies in relation to systems.[8] The first is 'technical arrangements as forms of order' which are,

> Ways in which specific features in the design or arrangement of a device or system could provide a convenient means of establishing patterns of power and authority in a given setting. Technologies of this kind have a range of flexibility in the dimensions of their material form. It is precisely because they are flexible that their consequences for society must be understood with reference to the social actors able to influence which designs and arrangements are chosen. (Winner 1995, p.38)

The second is 'inherently political technologies',

> In which the intractable properties of certain kinds of technology are strongly, perhaps unavoidably, linked to particular institutionalized patterns of power and authority... here, the initial choice about whether or not to adopt something is decisive in regard to its consequences. (Winner 1995, p.38)

This means that, "certain kinds of technology do not allow such flexibility, and that to choose them is to choose a particular form of political life" (Winner 1995, p.32). This link between a technology and certain 'political lives' has been argued to exist because technologies 'require' certain social and material conditions due to practical necessities. This follow the reasoning that, "the adoption of a given technical system actually *requires* the creation and maintenance of a particular set of social conditions as the operating environment of that system" (Winner 1995, p.33). However others argue that it is because certain technologies are strongly 'compatible' with certain systems (Markard & Truffer 2006). Winner (1995) critiques this argument in that, "a given technology is strongly *compatible* with, but does not strictly *require* social and political relationships of a particular stripe" (Winner 1995, p.33). The implications of technology are not always purposeful or have 'conscious conspiracies or malicious intentions' such as with the example of the long standing neglect of accessible infrastructure for handicapped persons

[8] Winner (1995) uses the term politics to mean, "arrangements of power and authority in human associations as well as the activities that take place within those arrangements" (Winner 1995, p.30).

in public places (Winner 1995). The critiqued argument of Winner (1995) is more accurate in that it is overly restrictive to state that certain technologies ‘require’ rather than are simply ‘compatible’ with specific social or political relationships and system configurations. There are often many different ways technologies can be adopted even though in practice they may only be adopted in a small number of different ways.

2.1.4. Innovation Studies

Innovation studies is a field of research concerned with the, “economics, policy and management of technological innovation” (Godin 2010, p.3). Although technological innovation has been studied for over a hundred years, that specific field of ‘innovation studies’ emerged roughly twenty five years ago (Godin 2010). Three key innovation studies concepts for transitions studies are discussed in this section: radical and incremental innovations, Large Technical Systems (LTS), and path dependency and lock-in.

Radical and Incremental Innovations

There are two types of innovations: radical and incremental. Radical innovations, “involve discontinuous change and the introduction of new technologies and techniques” (Gouldson & Murphy 1998, p.25). In contrast incremental innovations, “involve continuous improvement to existing technologies and techniques” (Gouldson & Murphy 1998, p.25). The difference between a radical innovation and an incremental innovation is that incremental innovations are, “minor changes in existing products, whereas radical innovations represent an entirely new class of products or technological devices based on a novel set of engineering and scientific principles” (Markard & Truffer 2006, p.612). However, radical innovations often rely on incremental innovations in order to be successfully diffused as described by Gouldson and Murphy (1998),

> While radical innovations often rely on incremental improvement for their success, it is apparent that incremental innovation must eventually encounter diminishing marginal returns as it encounters both economic and technical limits. The limits are maintained by those elements of the existing system that remain fixed. The periodic introduction of radical or

> discontinuous change is thus a prerequisite for subsequent phases of incremental innovation. (Gouldson & Murphy 1998, p.26)

Innovation is an important part of sociotechnical transitions and takes place in niches (one of the three levels of the MLP described in the next section). Radical innovations occur in niches because there is temporary protection for a new product or technology from the prevailing regimes standards and selection rules (Markard & Truffer 2006). The diffusion of a radical innovation, which can also be understood as a sociotechnical transition, is dependent on a number of factors as described by Gouldson and Murphy (1998),

> The initial adoption and subsequent diffusion of a radical innovation depend not only on its inherent characteristics but also on the nature of the selection environment. Thus, innovations which display some complementarity with existing systems are more likely to be adopted than those which do not. In this respect, even radical innovations are likely to reflect some of the path-dependences. (Gouldson & Murphy 1998, p.29)

As this quote describes, radical innovations tend to follow certain amounts of path dependency.

Large Technical Systems (LTS)

Large Technical Systems (LTS) can be characterized as being highly stable and having inertia. The type of innovations in these large technical systems, "tend to be incremental in nature and existing products and technologies undergo processes of slight, continuous improvement rather than radical change" (Markard & Truffer 2006, p.611). This tendency towards incremental innovation in LTSs is in contrast to a radical innovation is explained by Gouldson and Murphy (1998),

> Innovations depend upon a system or network of relations without which their adoption would be impossible. As a consequence, new technologies and techniques must be introduced into systems which have often been developed for and adapted to older technologies and techniques. The introduction of an invention into one part of an existing system may require far-reaching changes to other parts of the system to ensure compatibility with the system as a whole. Considerable resistance and inertia may be apparent in this respect. (Gouldson & Murphy 1998, p.27–28)

Energy systems tend to be large technical systems. For example, there are many technological regimes in the electricity supply sector that exist because it is a large, complex technical system including various sources including for example: wind, hydropower, nuclear power, and fossil fuel-based power (Markard & Truffer 2006). These technological regimes can then be understood from an aggregated level as a sector regime because of the dominant structure with large centralized power plants connected by long-distance transmission lines (Markard & Truffer 2006). Within this sector regime, "technological regimes may either equally co-exist within a large technical system, e.g. with similar market shares, or there may be a dominant regime and niches, respectively" (Markard & Truffer 2006, p.611). The technological regimes within the sector regime can co-evolve with more mature technologies becoming more powerful, rigid and diffuse (Markard & Truffer 2006). For example, wind energy is a minor component in the electricity supply system but it is growing (Markard & Truffer 2006).

Winner (1995) finds that, "certain devices and systems almost invariably linked to specific ways of organizing power and authority" (p.34). Large technical systems, such as electricity production systems, tend to be centralized because, "many large, sophisticated technological systems are in fact highly compatible with centralized, hierarchical managerial control" (Winner 1995, p.36). The argument was made by Chandler (1977) (in The Visible Hand) that certain technologies require certain scales with their associated social form of large-scale centralized, hierarchical organization to be administered by skilled managers in order to be plausible, such as transportation, production (electricity), and communication.[9] Building from Chandler's argument Winner (1995) states that it is the, "properties of many modern technologies – oil pipelines and refineries, for example – are such that overwhelmingly impressive economies of scale and speed are possible" (p.33). By choosing a specific technology, this means certain types of systems and infrastructures are required to operate it and at specific scales, therefore many implications are created and more than just an energy source has been committed to.

[9] Chandler (1977)'s book The Visible Hand was in response to Adam Smith's concept of the 'invisible hand' which referred to market forces and their ability to self regulate the economy. The 'visible hand' is the visible hand of management that Chandler argues has replaced what was the 'invisible hand'.

Path Dependency and Lock-in

Path dependency and lock-in can act as barriers to the introduction of innovations and are often characteristic of large systems. Path dependency occurs due to lock-in mechanisms that are mutually reinforcing and intricate. These mechanisms can include: investments, infrastructure, technical knowledge base, core beliefs, vested interests, behavioural patterns, subsidies, and regulations (Turnheim & Geels 2012; Unruh 2000). Path dependency and lock are rooted in evolutionary economics however are often discussed in sociotechnical transitions literature (Smith et al. 2010; Upham et al. 2014; Seyfang & Haxeltine 2012).

For technical arrangements as forms of order, the crucial point for change is when the initial choice of an artefact is made because the original flexibility disappears because the commitment has been made and there is a lock-in affect and path dependency. As Winner (1995) describes,

> By far the greatest latitude of choice exists the very first time a particular instrument, system, or technique is introduced. Because choices tend to become strongly fixed in material equipment, economic investment, and social habit, the original flexibility vanishes for all practical purposes once the initial commitments are made. In that sense technological innovations are similar to legislative acts or political foundings that establish a framework for public order that will endure over many generations. For that reason, the same careful attention one would give to the rules, roles, and relationships of politics must also be given to such things as the building of highways, the creation of television networks, and the tailoring of seemingly insignificant features on new machines. (Winner 1995, p.32–33)

This path dependency and lock-in mean that, “local, short-term contingencies can exercise lasting effects” (Mackenzie & Wajcman 1999, p.20).

In the case of the electricity supply system, Markard and Truffer (2006) describe how it is exhibiting, “strong path dependencies and high barriers for radical innovations” (p.609). The electricity supply system tends to be strongly path dependent because, “most system components are closely interrelated and various kinds of technical norms, organizational practices and institutions procedures have emerged to guarantee a smooth joint operation of all these components" (Markard & Truffer 2006, p.609). The complexity of the electricity supply system is a characteristic linked to path dependency as noted by Mackenzie and Wajcman (1999),

> Complexity and uncertainty, however, increase rather than diminish the importance of path-dependence. If there is an unequivocally superior alternative to what historical processes of technological change have left us with, then, as noted above, there will often be reasons for modest confidence that it will be adopted. If, on the other hand, the characteristics of alternatives are uncertain and contested, then the low-risk course will be the path-dependent one of starting from what history has given us and seeking to improve it. (Mackenzie & Wajcman 1999, p.21)

This has implications for a transition in the electricity sector towards low carbon sources as Calvert and Mabee (2014) describe,

> The social and environmental imperatives to replace non-renewable with renewable energy (RE) resources are strong, and the technological means by which to achieve this goal are available and improving. The problem however, is that a systemic and self-referential preference for fossil energy resources has been deeply entrenched within social and political-economic activities as well as their underlying institutional and physical structures over the last three centuries. (Calvert & Mabee 2014, p.2)

Fossil fuel related industries are likely to resist the shift towards renewable energy and therefore it will be a gradual abandonment of the current regime in relation to the increase of social, political, and economic pressures (Turnheim & Geels 2012). These cause incremental alterations to be encouraged over radical changes (Geels 2002). The emergence of a new sociotechnical system requires large changes to all aspects of the existing system.

2.2. Sociotechnical Transitions

Sociotechnical systems change over time and evolve into new systems. This process has come to be referred to as a transition. In the past it has also been termed a technological transition with a formal definition of where, "major technological transformations in the way societal functions such as transportation, communication, housing, feeding, are fulfilled" (Geels 2002, p.1257). This approach stems from the sociology of technology and innovation studies (Geels 2002).

The amount of research and literature on sociotechnical transitions is growing. However it still remains an area that deserves further study not least because of climate change and the sociotechnical transitions required to adapt to it. The earliest work in this area discussed technological regime transitions or shifts (Kemp 1994; Kemp et al. 1998; Rip & Kemp 1998; Schot et al. 1994; Schot & Rip 1996) however work did not 'take off' until the 2000s (Elzen et al. 2004; Geels 2002; Geels & Schot 2007; Murphy & Smith 2013; Rotmans et al. 2001; Scrase & Smith 2009; Turnheim & Geels 2012). This research has examined sociotechnical systems with respect to food, water, transport, technology, and energy (Elzen et al. 2004; Geels 2002; Murphy & Smith 2013; Scrase & Smith 2009).

Sociotechnical transitions utilize a systems approach that examines the interactions and relationships between social and technical elements. The primary focus of the work has been on radical innovation emergence as opposed to other aspects such as the destabilisation of existing regimes (Turnheim & Geels 2012). Historical case studies are frequently used and have the advantage that they generally are completed historical events thus allowing the entire process to be examined (Turnheim & Geels 2012). There are two main (and linked) approaches within the sociotechnical transitions literature: the multilevel perspective (MLP) and transition management (TM). This section examines the MLP because MLP research focuses on understanding the transition process whereas TM is largely concerned with how to 'actively steer' technology innovation and uptake (Genus & Coles 2008). It is questionable whether it is possible to truly manage and 'actively steer' a transition.

The MLP has been applied to sociotechnical transitions and has attracted a fair amount of attention (Geels 2002; Genus & Coles 2008; Markard & Truffer 2008; Rip & Kemp 1998; Smith & Stirling 2010). This perspective is a middle range theory and aims to examine the complex dynamics of sociotechnical changes through analytical and heuristic concepts from various literatures (Geels 2010; Murphy & Smith 2013). The

MLP and socio-technical systems are important heuristic devices in the way they structure and bring attention to the different levels of niche, regime, and landscape (Hodson et al. 2015). The MLP is operationalized in Chapter 6 Existing Energy System as a heuristic device by using the three levels of the MLP to outline recent developments around renewable energy technology and policy in Scotland. The MLP levels are particularly useful because of the complexities involved in sociotechnical systems. They are particularly valuable for, “structuring the usually messy accounts of complex system dynamics” (Späth & Rohracher 2012, p.465). It allows for different aspects of a system to be understood over time such as, “to assess transition dynamics and activities which aim to bring about radical or incremental systemic change” (Hodson et al. 2015, p.2). Although it can be challenging to separate and define the systems and their levels; therefore this requires extra clarity and attention.

The MLP has three levels to examine sociotechnical transitions: niche (micro level), regime (meso level), and landscape (macro level). The three levels have a nested character because niches are embedded within regimes, and regimes within landscapes (Geels 2002). Niches are required for radical innovations to be nurtured by dedicated actors because they need protection from the regime to survive (Geels 2010). This protection is necessary because radical innovations tend to be expensive and cumbersome and would not be supported by the regime (Geels 2002). Hodson et al. (2015) describe the relationship between the three parts of the MLP as follows,

> Niche activities can be but not necessarily are responses to landscape pressures and may aim to put pressure on different regimes in more or less strategic ways. Processes of experimental configuration, strategy and learning are important to niche construction as is the extent to which niches generate momentum and, for this, the relationship of niches to regimes. (Hodson et al. 2015, p.3)

Niches can be formed by policy makers with goals to develop novel technologies or by actors that are well-resourced (Markard & Truffer 2006). Market niches can also form due to, “demand of specific customer segments or particular application contexts in which a novel technology might be superior to the established technology” (Markard & Truffer 2006, p.612). Fringe actors or outsiders in small networks tend to be the ones to carry and develop niche-innovations (Geels & Schot 2007). The shift of a technology from one niche to another is challenging and involves experimentation, adjustments, reconfigurations, and learning (Geels 2002).

Regimes are the dominant practices, rules, and shared assumptions that guide activities within communities (Rotmans et al. 2001). Geels (2002) identifies seven dimensions within the sociotechnical regime: technology, user practices and application domains (markets), symbolic meaning of technology, infrastructure, industry structure, policy, and techno-scientific knowledge. These dimensions are linked with internal dynamics and co-evolve over time. Regimes shift gradually through processes of reconfiguration and cascade dynamics where one element change triggers others on all dimensions (Geels 2002). Regimes are stabilised and locked-in through numerous mechanisms and commitments: cultural-cognitive institutions (focus), missions and identities, existing technical competencies, and commitments from industry actors to industry-specific regulatory institutions (Turnheim & Geels 2012). For example, Geels (2014) argues that regime stability is the result of incumbent actor's active resistance. However, radical innovation can be created or supported by incumbents, not just new entrants (Mazur et al. 2015).

Landscape is the context and external factors in which interactions and changes take place (Geels 2002). The timing of landscape pressures on regimes will affect the outcome of the development of niche-innovations, creating different transition paths (Geels and Schot 2007). Landscapes take longer to alter than regimes (Geels 2002). Examples of types of landscape change include population demographics, broad political changes, and cultural changes. However, extreme events or shocks can either halt or accelerate regime destabilisation (Turnheim & Geels 2012). Crises provide a ‘sense of urgency’ which in turn increases public and political pressure. Macro-economic events affect market demand, future expectations, and competitive positions. Landscape cannot be influenced by actors in the short run (Geels and Schot 2007).

Actors and organisational networks are embedded in the sociotechnical system within a landscape context and their perceptions and actions are guided by the regimes and rules (Genus & Coles 2008). Government and policy makers set the rules and regulations for industry. Governments, "support and shape economic sectors in specific ways, e.g. through tariff protection, loans, cash grants, government purchases, patents, tax concessions, information and research services" (Geels 2014, p.26). Policy also plays an important role in supporting (e.g. subsidies) or destabilising industries. They achieve this through mechanisms such as subsidies to support specific industries and through altering economic frame conditions such as taxes, import restrictions, and regulations (Turnheim & Geels 2012). However, industry tends to have close contact with policymakers since industry is often consulted, and therefore ideas and interests can possibly be internalized by policymakers, as well as direct lobbying or information strategies or incentives.

The MLP views transitions as the product of developments within and between the three levels that create new alignments (Geels & Schot 2007). The MLP understands transitions, "as arising from the interplay between multi-dimensional developments at three analytical levels" (niche, regime, landscape) (Geels 2014, p.22). A sociotechnical transition is the change from one sociotechnical regime to another (Geels & Schot 2007). The process begins with radical niche innovations that build momentum and support from powerful groups as well as price and performance improvements. Landscape level pressures on the regime destabilize it, creating opportunities for the radical innovations to break out of the niche and become dominant. A transition is complete when the new sociotechnical regime has become 'socially embedded' (Genus & Coles 2008). This process is represented in Figure 4 from Geels (2002) where the arrows represent changes over time and overall interactions between the three levels. Translation, whereby radical innovations become a part of the regime from the niche is, "rarely a process between equals" as stated by Smith (2007). Regimes are a result of relatively large time scales where there are interactions between users, technologies, knowledge, and institutions, which are highly embedded and influential. In contrast niches are poorly embedded (Smith 2007).

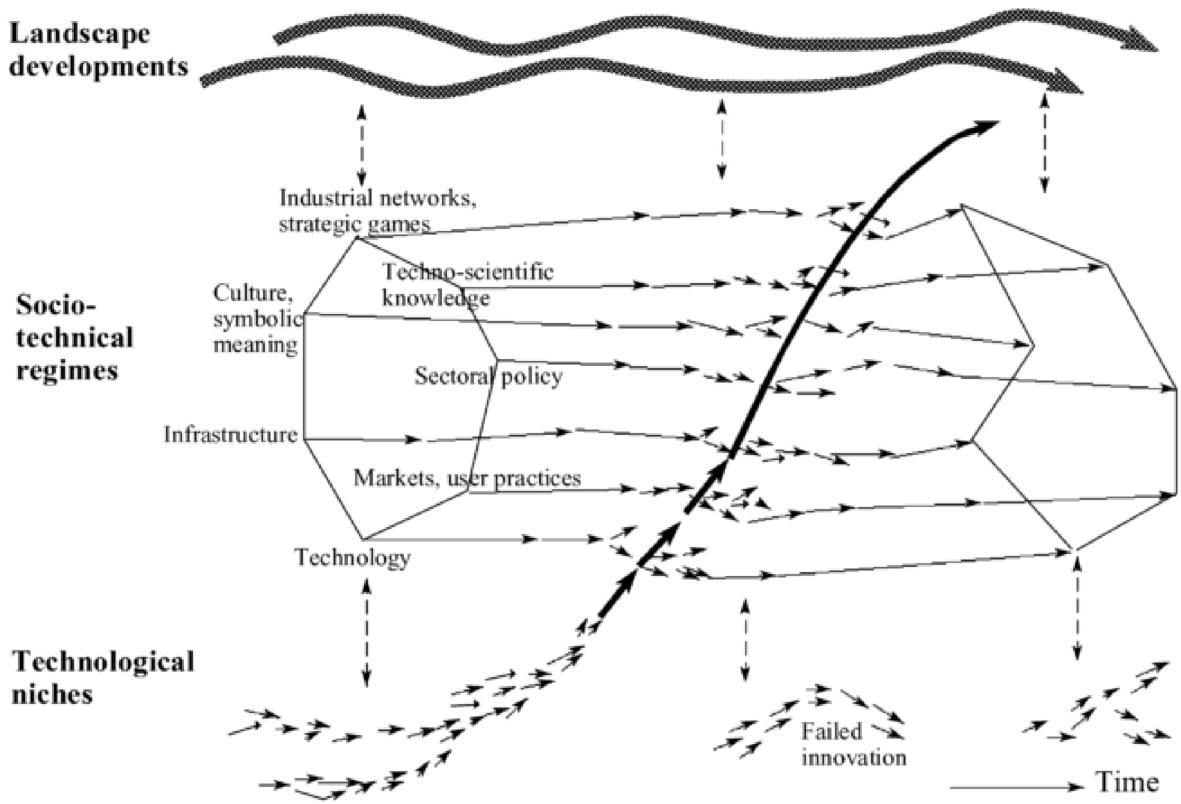

Figure 4 Multilevel perspective dynamics (Source: Geels 2002, p.1263).

Rotmans et al. (2001) suggests that transitions can also be conceptualized to occur in four phases: predevelopment, take-off, breakthrough, and stabilization. These stages are identified in Figure 5 with the level of social development through time. From left to right: initially the dynamics equilibrium is intact, then the take-off process of change begins with increasing development and accelerates, breaks through the regime, and finally stabilizes at an increased level of social development. Transitions can vary by three system dimensions: speed of change, size of change, and time period of change (Rotmans et al. 2001). Transitions are the result of short term flow developments and long-term stock developments (Rotmans et al. 2001). These transitions occur within different domains and each domain has different speeds at which it changes (e.g. economics quickly, ecological systems slowly, institutional and technological in the mid-range) (Rotmans et al. 2001).

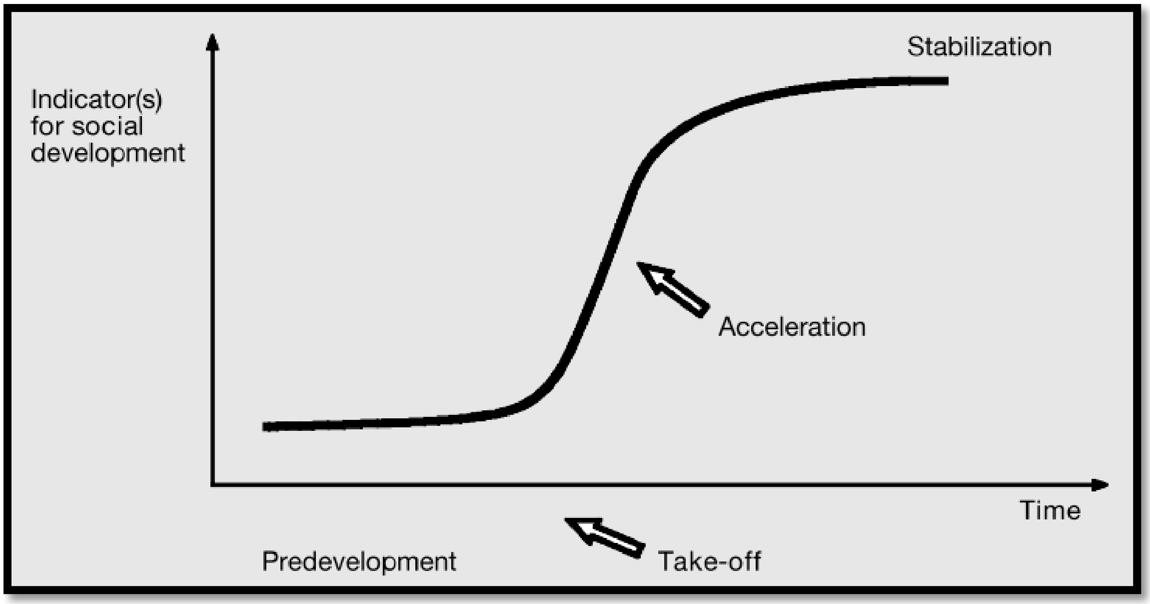

Figure 5 Four phases of transition (Source: Rotmans et al. 2001, p.17).

The four stages of the sociotechnical transition described by Rotmans et al. (2001) have similarities with Rostow's (1959) Stages of Growth model. Rostow's (1959) model generalizes economic development. Both models begin with equilibrium that is followed by a "take-off" stage of rapid development, and then development slows to a new state of equilibrium. With Rostow's (1959) model this equilibrium state is mass consumption and with Rotmans et al. (2001) model it is a new stable level of social development. Rostow's model has been fairly criticized for the assumption that economic development fits into a linear system because empirical evidence shows countries do not always follow the model with some 'taking off' and then 'slipping back'. It has also been criticized for being biased towards a western model of development rather than an international model (Stubbart & Smaley, Roger 1999).

Transitions have a range of possible pathways in terms of direction, scale, and speed (Rotmans et al. 2001). The pathway taken is dependent on the nature of the radical innovation and the characteristics of the niche, regime, and landscape. The timing of landscape pressure on regimes will affect the outcome of the development of niche-innovations, creating different transition paths (Geels & Schot 2007). Geels and Schot (2007) identify four transition pathways: transformation, reconfiguration, technological substitution, and de-alignment and re-alignment. The event sequences of the four transition pathways are not automatic nor do they always follow their 'pure forms' but they can create a pattern of sequential crossovers. Geels and Schot (2007)'s transition pathways provide a more nuanced approach to understanding the stages of a transition as compared to Rotmans et al. (2001)'s simplistic phases of the transition model (shown in Figure 5).

The MLP is often treated as a global (macro) (between countries) or national (within countries) model to understand the entire transition process (Geels & Schot 2007; Hodson et al. 2015). Raven et al. (2012) conducted a literature review to examine the proportion of empirical transition studies at each scale and, as shown in Figure 6. It found a large emphasis on the national and conceptual/not articulated papers. This focus on the national scale of empirical transition studies is not in line with processes of globalisation and regionalisation in science, innovation, and technology (Raven et al. 2012). There is a fair amount of research on the role of cities or the urban in sociotechnical transitions research (Bulkeley 2006; Bulkeley et al. 2010; Castan Broto & Bulkeley 2012; Wolfram & Frantzeskaki 2016; Frantzeskaki et al. 2014). This is in contrast to the lack of identification shown in Figure 6 of research on specifically the rural. However, the dynamics at the local level, "can be shown in elaborate single case studies" (Geels & Schot 2007, p.414). This research contributes to this currently lacking area of research on the rural identified by Raven et al. (2012) as well as well as other scales and utilizes a number of cases to achieve this.

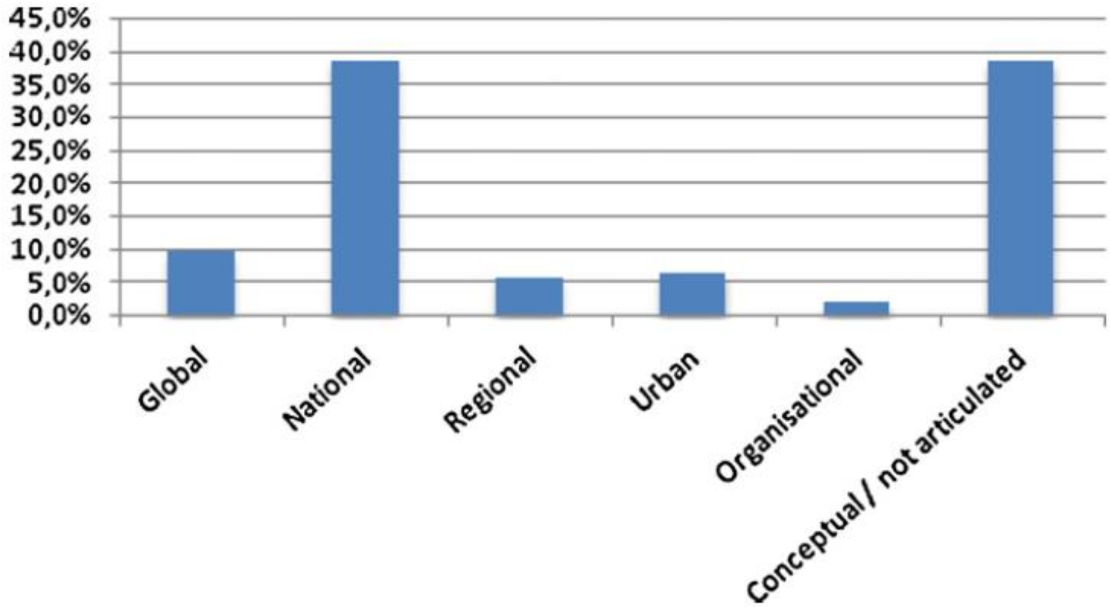

Figure 6 Diagram of published papers from 1994-2011 in transitions studies delineated by geographical focus (Source: Raven et al. 2012, p.64).[10]

The difficulty with the MLP is that it is complex and requires a large amount of data, and it is difficult to create boundaries with the analysis of regimes due to their broad nature (Geels 2002). A criticism of the MLP is the lack of focus on political power and agency (Geels 2014; Genus & Coles 2008; Smith et al. 2005). It has also been suggested that the approach would benefit from the inclusion of an appreciation for 'multi-level governance' and scale of politics (Hodson & Marvin 2009). The influence and importance of geography has also been neglected by sociotechnical transition research (Coenen et al. 2012; Lawhon & Murphy 2011; Chandrashekeran 2016). There is a lack of contributions in the sustainable transitions literature that explicitly deal with the importance of local resource endowments (Hansen & Coenen 2015). Additionally the literature has emphasised large-scale, long-term change rather than local-scale, unique processes and outcomes (Murphy & Smith 2013). Nonetheless, the MLP has been a highly effective framework for generating understandings of sociotechnical transitions (Murphy & Smith 2013). This study addresses some of these critiques particularly around geography by developing the MLP to become a more geographically sensitive and multi-

[10] Global includes studies focused on the world, continents, or 'developing countries'. National includes analysis of a country. Regional is a sub-national focus. Urban is the focus of specific cities. The Conceptual/not articulated category are papers that are mainly theory with no overt geographical delineation.

scalar model as shown through the analytical framework developed in Chapter 4 Towards an Analytical Framework.

2.3. Sociotechnical Transitions and Energy

There has emerged a scientific and policy consensus that climate change is occurring and that it is anthropogenic. The need to drastically reduce greenhouse gas (GHG) emissions has also become widely accepted. Goals have been set by many countries such as in the UK through the UK Climate Change Act (2008) with a mandatory target of GHG emission reduction levels of 34% by 2020 and 80% by 2050 (based on 1990 levels) (DECC 2009c). To meet these targets the UK has reduced its GHG emissions by 33% between 1990 and 2014 (Scotland has made a 39.5% reduction) (Committee on Climate Change 2016). These are reduction goals that will likely require a major shift to low carbon energy sources therefore it is a question of what kind of transition it will be rather than if it will occur (Hodson et al. 2015). This shift will transform the production, consumption, and governance of energy, and include a reconfiguration of the current sociotechnical system (Murphy & Smith 2013; Rip & Kemp 1998).

In response to the increasing awareness of the need for sustainability, the field of 'sustainability transitions' has grown significantly over the past 10-15 years with an output of 60-100 academic papers published per year (Markard et al. 2012). Sustainability transitions are, "long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard et al. 2012, p.956). It is important to note that what is considered more 'sustainable' is subjective and likely to change over time. This sustainability transitions literature is broad in terms of topics (energy, transportation, water, etc.), approaches, methodologies, and fields of study it crosses (management studies, sociology, policy studies, economic geography, modelling, etc.) (Farla et al. 2012; Markard et al. 2012). However, the topic of energy in this field has acquired a significant amount of attention. Sovacool (2014) conducted a content analysis of published articles (1999-2013) within the field of energy studies and found that the social sciences aspect of energy (including fields of history, sociology, philosophy, political science, and psychology) has been treated as secondary or peripheral to that of the 'hard' aspects of energy (including economics, statistics, mathematics, physics, and engineering). The topic of geographic space and scale was the least favoured topic found in the analysis with only 1.1% of articles on the topic (Sovacool 2014). This study contributes to this limited geographic field of literature in the field of energy studies.

Thus far energy transitions towards sustainability, such as to renewable energy sources, have received more attention in the literature than water, food, and other domains (Markard et al. 2012). An energy transition is described by Calvert and Mabee (2014) to be, "measured through time as a gradual shift from one mix of resources and technologies to another" (p.2). Although accurate, this description by Calvert and Mabee (2014) focuses on technology and neglects the important aspect of the social such as the charateristic increase in energy consumption with a transition. The term 'low-carbon transitions' is used in some of this literature which Geels (2014) argues has focused too much on green niche-innovation (Geels 2014). The energy system is complex with networks of actors, societal norms, infrastructure, and institutions (rules). The many actors involved include businesses, policy-makers, research institutes, regulators, investors, and end-users (Scrase & Smith 2009). Market mechanisms and policy measures establish the rules and standard practices for the industry. However, change in the system is constrained by material infrastructures and existing actors' commitments (Scrase & Smith 2009). It is also constrained by 'trust in the system' which can, "make it extremely difficult to re-direct regimes toward more sustainable outcomes" even when there are, "safer and/or more sustainable alternatives" (Murphy 2015, p.8–9).

The complexity of the renewable energy shift makes it useful to apply the sociotechnical transition approach to understand the transition (Murphy & Smith 2013; Scrase & Smith 2009; Turnheim & Geels 2012; Verbong & Geels 2010). A large amount of this research focuses on historical energy shifts to make recommendations for the renewable energy transition (Allen 2012; Bennett 2012; Fouquet 2012; Fouquet & Pearson 2012; Solomon & Krishna 2011; Wilson 2012). Research on past technological transitions is useful because these transitions have been found to follow similar patterns with different features depending on the context, actors, and technologies involved (Bennett 2012). However it is important to research current energy transitions as this study does by examining the renewable energy transition in Scotland in order to inform current transitions.

The public awareness of climate change is considered to be the main landscape pressure that will cause a renewable transition to occur (Geels & Schot 2007; Murphy & Smith 2013). Attention on climate change grew rapidly in the early 2000's, however this attention has shifted since the financial-economic crisis towards jobs, competitiveness, and energy prices (Geels et al. 2015). The annual number of national UK newspaper articles including the word 'climate change' can be seen in Figure 7 from Turnheim and Geels (2012).

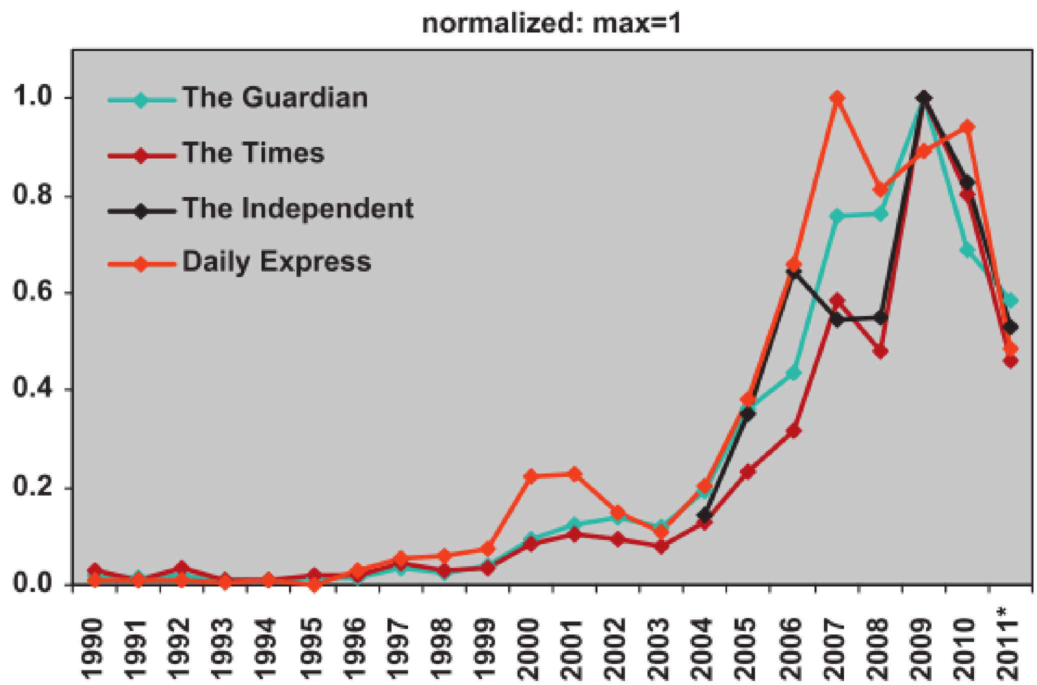

Figure 7 Annual number of national UK newspaper articles including the words 'climate change' (Source: Turnheim & Geels 2012, p.47).

There are inevitable challenges involved with a transition and the processes of reconfiguration because a new sociotechnical system is created from an existing system that is deeply embedded and initially dominant (Unruh 2000). This difficulty is clear in the case of the development of renewable energy projects because the current energy system is built mainly on fossil fuel generated energy and is organized to maximize the production, distribution, and consumption of fossil fuel sources (Murphy & Smith 2013).

In order to transition to renewable energy sources new infrastructure and distribution systems must be built which requires large capital investments, skilled workers, specialized knowledge, and a profitable market. The levels of change required in the various parts of a system depend on the radical innovation. This is exemplified by Markard and Truffer (2006)'s diagram of the electricity system (Figure 8). This diagram represents the electricity supply value chain with five major components: exploitation of primary energy carriers, their transport, their conversion into electricity, power transmission and distribution, and power markets and sales. The figure also displays the level of innovation or 'degree of horizontal novelty' required at each of these components of the electricity supply value chain for: nuclear power, combined cycle gas turbine (CCGT), wind power, and fuel cells. Wind power is particularly interesting because it requires high levels of horizontal novelty for nearly all the components of the value chain. Wind power therefore, "leads to a competition of regimes in the field of power generation and on the level of the sector because, like other distributed energy sources, wind power is largely incompatible with the dominant regime of centralized generation" (Markard & Truffer 2006, p.611). The existing regime will also resist a transition as argued by Geels (2014) who states that the coal, gas, and nuclear production regimes in the UK are currently resisting and are resilient. This negates benefits that could be made from renewable energy production deployment.

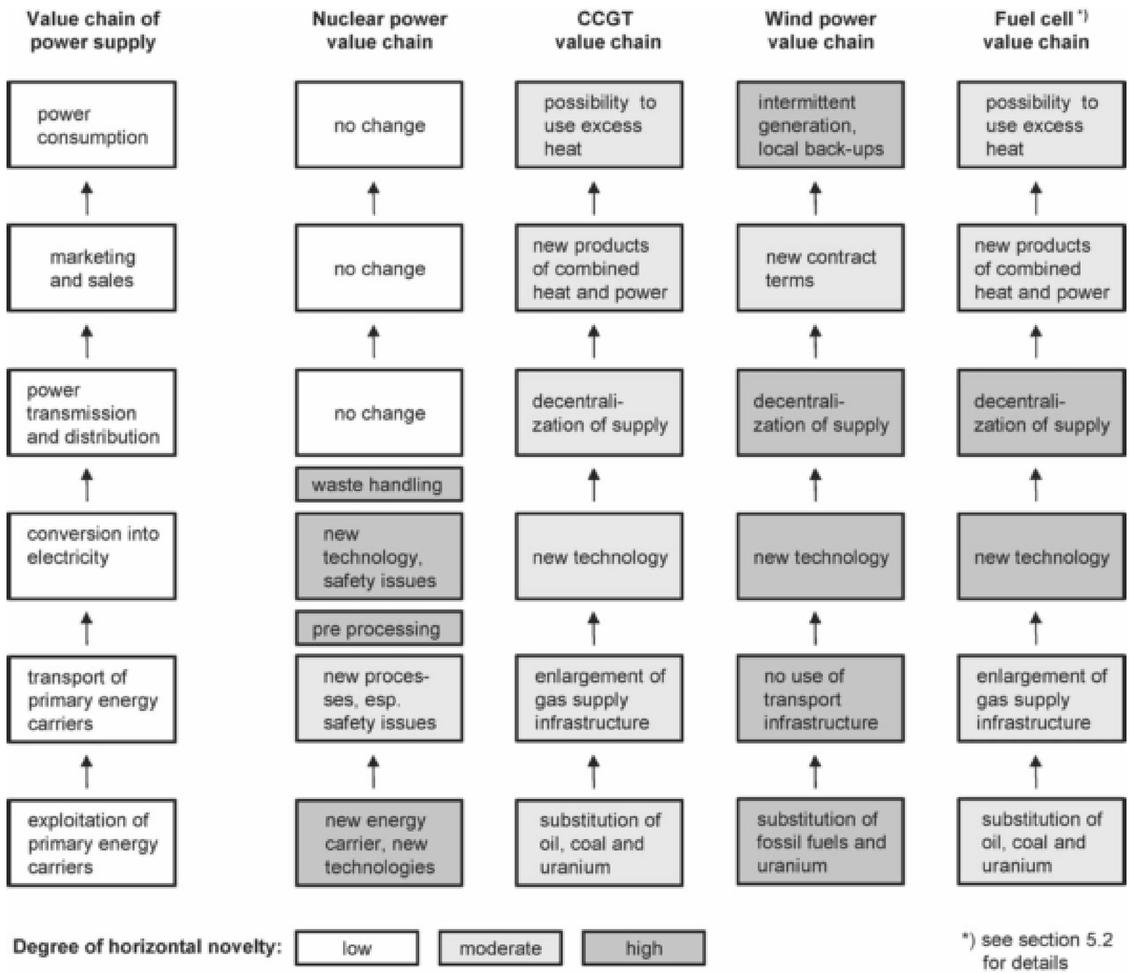

Figure 8 Markard and Truffer (2006)'s model of the realized and potential changes in the traditional value chain of electrical power supply due to the introduction of new technologies (Source: Markard & Truffer 2006, p.613).

Geels et al. (2015) presents a diagram of the electricity generation sociotechnical system (Figure 9). This diagram shows a basic overview of the electricity system from generation, transmission, and consumption.

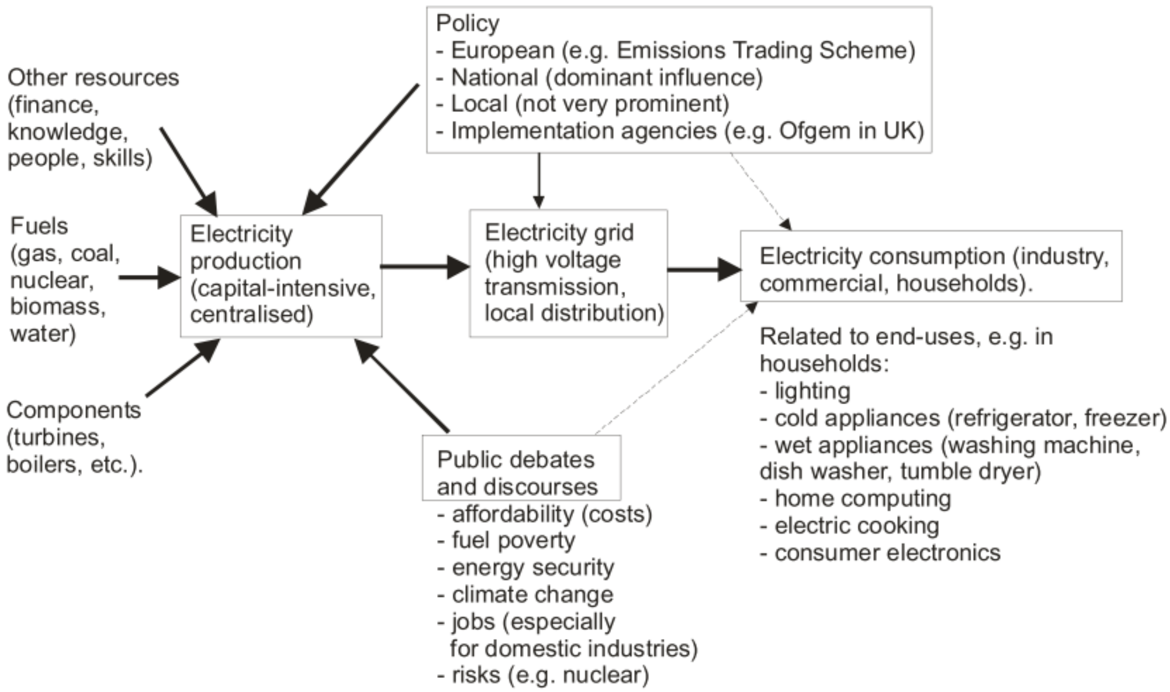

Figure 9 Geels et al.'s (2015) diagram of the sociotechnical system in electricity (Source: Geels et al. 2015, p.7).

The electricity supply system can be understood as, "a set of different actors, institutions and technical components and their relationships that serve the purpose to supply consumers with electrical power" (Markard & Truffer 2006, p.613). The system involves capital-intensive infrastructure with a range of technologies and components as well as a range of actors and institutions (Markard & Truffer 2006). Although the diagram above is highly simplified it is a useful way to conceptualize the electricity supply system.

Past energy transitions suggest that they are characterized by significant increases in energy consumption (Fouquet 2009; Grubler 2012). Fouquet (2009) describes how the transitions to coal, then oil, then natural gas have all also involved increases in energy consumption over time. This characteristic is of concern for the shift to renewable energy because if larger energy consumption accompanies the shift to lower GHG emission energy sources, then the desired decrease in total GHG emissions would be more difficult to achieve (Fouquet & Pearson 2012).

In understanding a current sociotechnical transition it is important to recognize at which stage of a potential transition we are at. Turnheim and Geels (2012) describe the state of the current shift to renewable energy to be between phase 2 and 3 of their destabilisation phase model (shown in Table 3). According to Turnheim and Geels (2012) phase 1 occurred in the 1990s when fossil fuel firms contested the existence of climate change. Phase 2 was achieved when the industry acknowledged there was a problem (climate change) and incremental innovations began to be implemented in response to public concern. The diversification of Phase 3 can be seen in the increase of renewable energy use. However there is a lack of commitment thus far due to concerns about the economic viability of these alternatives. In order to move into the next phase, Turnheim and Geels (2012) suggests there needs to be: increased public support, stronger supportive policies, increased pressure from radical alternatives, and industrial problems. Hodson et al. (2015) emphasizes the role of institutions in the low carbon transition because, "institutions at a national level transform wider-landscape economic, ecological and political pressures into policies and, through their historically generated priorities, set conditions that enable, favour or disenable particular forms of low carbon activity at other levels, mostly through economic priorities, standards and regulation" (Hodson et al. 2015, p.4). A crisis or series of crisis events may be needed in order to move into the fourth phase.

Table 3 Phase model of destabilisation (Data Source: Turnheim & Geels 2012, p.38).

(1) Blindness and denial	External pressures are initially weakly articulated. Industry actors initially deny performance problems or see them as temporary. They downplay problems and follow a 'business as usual' mode, with strong regime commitment.
(2) Incremental responses to problems	External pressures become better articulated and linked to performance problems. Industry actors recognize the problems, but strategies remain defensive, focusing on tighter controls, incremental innovation strategies, and early diversification. Regime commitments remain strong.
(3) Increasing doubts and diversification	Increasing pressures and problems create performance gaps, which lead industry actors to begin doubting the viability of (elements of) the existing regime. Industry actors begin exploring solutions outside the bounds of the existing regime. These diversification and exploration activities signal weakening commitment.
(4) Decline and destabilisation	Problems turn into crises which raise the sense of urgency. Industry actors lose faith in the existing regime and implement drastic turnaround strategies. Depending on the severity of problems and the ability of industry actors to enact radical change, they can implement two types of change (Tushman and Romanelli 1985):

(4a) Reorientation	Substantial change in some regime elements (technology, knowledge base, regulations) focusing on the development of *new means* for survival.
(4b) Re-creation	Deeper changes to core regime elements (mission, identity, core beliefs), focusing on the development of *new hopes* for survival around a fundamentally changed industry.
(5) Dissolution	If these two types of change fail to address the mounting problems, actors lose faith and abandon the prospects for survival. Industries then try to make the most of decline: avoiding a full collapse and 'milking' the assets.

Historic energy transitions have occurred from over the span of decades up to more than a century in length and have been prompted by resource scarcity, high labour costs, and technological innovations (Grubler 2012; Solomon & Krishna 2011). It is expected that for low carbon transitions to occur in a timely manner, as is necessary to limit the impacts of climate change, a large amount of government encouragement will be required (Fouquet & Pearson 2012). However, the UK's Met Office has announced that global temperatures in 2015 (from data collected between January to September) have warmed by 1.02°C above the 1850 and 1900 average temperatures (MET Office 2015). Radical policy reform can accelerate regime destabilisation because policy can alter the economic conditions and suggest long-term signals (Turnheim & Geels 2012). Smaller systems or markets take a shorter period of time to change (Grubler 2012). Transitions tend to take longer if the incumbent system's infrastructure is intensive and if there are high levels of technological interrelatedness (Grubler 2012) which is related to the technological momentum of the system (Hughes 1983). The pre-existence of niches to develop new technologies speeds up the process as well as size of the comparative advantage of the new technology (Grubler 2012). Innovative technologies that eventually break into the regime take a long time to mature (Allen 2012). Will the transition to renewable energy be able to be sped up relative to past transitions? Geels (2014) suggests that, "politically-inspired regime destabilization may be necessary to create opportunities for the wider diffusion of renewables, which now face uphill struggles against resistant regimes" (p.37). Therefore, for the transition to renewable energy production to occur will there need to also be active regime destabilization politically?

A range of recommendations and pathways for the renewable energy transition have been made in the literature. Scrase and Smith (2009) suggest the best approach is for energy supplies to be centralized (such as by large offshore wind farms) so that energy can feed into national transmission networks very similarly to current more dominant energy sources. Allen (2012) also argues that decentralized decision making will not be the most effective way to transition away from high carbon producing energy sources because of the unaccounted externalities when people choose fuels or technologies. However, Scrase and Smith (2009) argue for a more decentralised system because they state it is more appropriate and effective for the expansion of renewable energy (Scrase & Smith 2009). Markard and Truffer (2006) describe the implications of different scales of wind power development,

> As long as wind power covers just some percent of electricity supply, its intermittent nature can be balanced with other power plants, i.e. a co-existence of the different regimes is technologically feasible. With a higher degree of diffusion, however, incompatibilities become increasingly costly, thus making the struggle of the regimes more and more virulent. Wind power, in other words, has a potential to foster a regime shift in the electricity supply system. (Markard & Truffer 2006, p.617)

It is possible for renewable energy to be developed in centralized and decentralized forms and examples of both approaches can be seen throughout the UK with many small-scale dispersed wind turbines as well as large-scale onshore and offshore wind farms. With any approach planning and coordination are crucial (Allen 2012). Additionally energy policies need to be persistent and continuous because energy transitions take place over large periods of time and technological innovation/knowledge needs to be nurtured continuously (Grubler 2012).

By better understanding the renewable energy transition, it will be possible to foster the shift that will help achieve the time sensitive GHG emission reductions necessary to limit the impacts of climate change. However, how much can or should policy makers and decision makers encourage the transition?

2.4. Sociotechnical Transitions: What About Geography?

Sociotechnical transition studies have tended to neglect the examination of geographical influences (Coenen et al. 2012; Hansen & Coenen 2013; Lawhon & Murphy 2011; Chandrashekeran 2016). Spatial context is too frequently considered a ‘passive background variable’ (Coenen & Truffer 2012). However over the past few years there has been an emerging interest in incorporating and understanding the geographical dimension of transition processes (Markard et al. 2012; Smith et al. 2010; Chandrashekeran 2016). Sociotechnical transition scholars have begun to engage with geography and some geographers have become involved in sociotechnical transitions research although there is much more work needed. Geographical dimensions of sociotechnical transitions are important for understanding how spatial contexts matter, institutional contingencies, and spatial unevenness that affect transition pathways (Coenen & Truffer 2012; Coenen et al. 2012).

2.4.1. Science, Technology and Innovation Studies and Geography

A limited amount of work has been done by STS and innovation scholars who have discussed geography and attempted to incorporate geographic concepts into the transitions concepts. Sengers and Raven (2015) incorporate geographic concepts and a more scalar and spatially nuanced model for niches by incorporating these concepts into the notion of the ‘local-global’ niche along with other geographic concepts such as buzz-pipelines, global production networks, and policy mobilities. Local in the ‘local-global’ niche notion refers to the specific location of the niche whereas the global is the connectedness through the locally specific lessons becoming generic mobile concepts through actor-networks translating the locally specific lessons. Wieczorek et al. (2015) also is part of an emerging literature addressing the geographical aspect of sustainable transitions by examining transnational sustainability transitions and embracing a multi-scalar approach to understanding the transition processes.

Scholars of innovation studies and STS have begun to incorporate geographic aspects into the MLP, some with the help of geographers. There is a need for better conceptualizations of geography and scale in the MLP framework (Lawhon & Murphy 2011; Chandrashekeran 2016). Späth and Rocracher (2012) note that, "concepts such as the multi-level perspective on socio-technical change have not given sufficient attention to space and place so far" (p.461). However, Hodson et al. (2015) argue that, "the MLP provides very important inroads to understanding the stability and dynamics of sociotechnical systems and that it can be improved to also reflect the spatiality of transitions" (p.3). Raven et al. (2012) criticize the MLP in that, "empirically the three levels (niche, regime and landscape) are often implicitly conflated with specific territorial boundaries: regimes tend to be depicted with national features (these being the focus of much empirical research); landscape dynamics with international features; and niches with (sub-)national or local features" (p.64). However Raven et al. (2012) also argue that this association of specific territorial boundaries with certain MLP levels is theoretically unnecessary because, "transitions do not simply occur within a certain territorially bounded space (e.g. a country), but emerge out of the tensions created in multi-scalar interactions between spatially distributed actors embedded in multi-level structures with different temporal dynamics" (Raven et al. 2012, p.70). Rather it is suggested that the MLP levels are associated with processes that have different structural modes and temporal dimensions that can hold a variety of different spatial positioning.

Raven et al. (2012) present a second generation of the MLP model to explicitly incorporate spatial scale. Table 4 describes the structural and spatial aspects of each part of the MLP. The MLP and its levels can be understood to have two main aspects: temporal and structural (Raven et al. 2012). It also includes the concept of relational scale which is constituted through networks of actors across space and time that produce the niche, regime, and landscape levels, and "emphasising networks that are enacted and structured across different levels of spatial scale" (p.69). Raven et al. (2012)'s spatially more sensitive MLP approach highlights the spatial aspects of the MLP levels but is only a starting point for incorporating these concepts which need to be integrated more thoroughly.

Table 4 Scales of the multi-scalar MLP as presented by Raven et al. (2012) (Data Source: Raven et al. 2012, p.72).

MLP level	Time	Structure	Space
Landscape	Long durée [duration], sometimes rapid change caused by disruptive events	Exogenous environment	Typical landscape networks exhibit high degrees of proximity and power across incumbent socio-technical system
Regime	Decades	Endogenous structures enacted by extensive organisational networks and embedded in institutions and infrastructures	Typical regime networks exhibit high degrees of proximity and power within an incumbent socio-technical system
Niche	0-10 years	Protective space that enables development of alternative structures	Typical niche networks exhibit low degrees of proximity and power within an emerging socio-technical system

Hodson et al. (2015) present a diagram (Figure 10) to show the ways in which transition activity can be understood as 'scalar'; from a top-down versus bottom-up approach (vertical axis) and the way in which transition activity reconfigures systems and spaces (horizontal axis). Spatial configuration, "is primarily concerned with constructing spatially or contextually embedded priorities for change" (Hodson et al. 2015, p.10). System configuration, "is primarily concerned with the purposive vision of low carbon transitions and with ensuring the public complies in playing their role as a delivery mechanism by adopting the new roles assigned to users" (Hodson et al. 2015, p.10). Hodson et al. (2015)'s diagram presents an interesting way of conceptualizing the scalar nature of transition activity however it does not address the scalar aspects of the various levels of the MLP (niche, regime, and landscape).

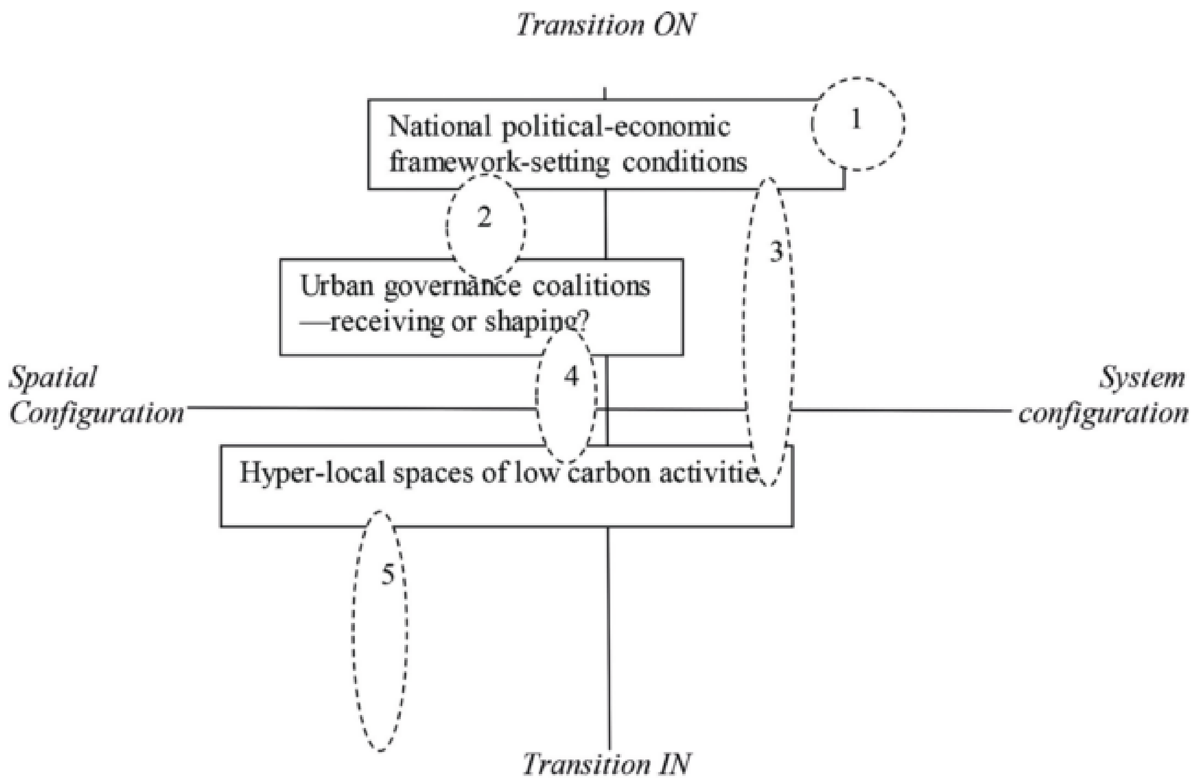

Figure 10 Hodson et al. (2015)'s diagram of the scalar interrelationships in transitions activities and chains of intermediary spaces (Source: Hodson et al. 2015, p.11).

STS scholars have also discussed the question of whether certain technologies have certain intrinsic political and geographical qualities. For example renewable energy has been connected to claims that some of these technologies are 'intrinsically democratic, egalitarian, and communitarian' (Winner 1995). For example, Winner (1995) describes the case of solar energy,

> Many advocates of solar energy now hold that technologies of that variety are more compatible with a democratic, egalitarian society than energy systems based on coal, oil, and nuclear power; at the same time they do not maintain that anything about solar energy requires democracy. Their case is, briefly, that solar energy is decentralizing in both a technical and political sense: technically speaking, it is vastly more reasonable to build solar systems in a disaggregated, widely distributed manner than in large-scale centralized plants; politically speaking, solar energy accommodates the attempts of individuals and local communities to manage their affairs effectively because they are dealing with systems that are more accessible,

> comprehensible, and controllable than huge centralized sources. (Winner 1995, p.34)

However, Winner (1995) argues that, "the social consequences of building renewable energy systems will surely depend on the specific configurations of both hardware and the social institutions created to bring that energy to us" (p.38). The flexible nature of renewable energy technologies mean that there are many potential ways the renewable energy system could be formed. Depending on the system's structure, Calvert (2015) argues that these technologies can achieve 'greater energy democracy' by, "hyper-distributed and less capital intensive energy production systems is not an inherent characteristic of a renewable energy socio-material assemblage, but is part of the tensions shaping the trajectory of these new assemblages" (p.12). Although there has been some effort for STS to incorporate geographical concepts into STS approaches as shown in this section of this chapter, there has not yet been enough weight given to geography such as with aspects of place and work to explore this.

2.4.2. Geographers and Transition Studies

Geographers have engaged with transitions studies and brought with them key geographic concepts of place, space, and scale. As described by Calvert (2015), by "building on socio-techical transitions theory, geographers are helping to unpack the ways in which local political, economic, cultural, and ecological trajectories shape technology diffusion and uptake in order to better understand the geographic conditions under which energy transitions specifically, but sustainability transitions more generally, are most likely to occur" (p.11). Including considerations of geography will allow for better understandings of why, where and when transitions occur unevenly across space (Lawhon & Murphy 2011). Also, examining more closely the configurations and patterns of these transitions will allow for better understanding of the underlying processes at play. Some research has explicitly begun to bring together geographical understandings with sociotechnical transitions such as relating to sustainability.[11] This section is organized into the three key aspects of geography: space, place, and scale.

The various parts of the sociotechnical transition have different spatial aspects. Spaces (e.g. cities, regions, neighbourhoods) as well as scales (e.g. city, regional, national) are, “continually being made, negotiated and remade” (Hodson et al. 2015, p.1). The importance of the spatial distribution of local resource endowments for considering the geography of transitions is noted by Hansen and Coenen (2015). This spatial distribution is particularly important when examining resource peripheries. Murphy (2015) categorizes socio-spatial context features as either structural or cognitive elements. Structural features are regulative elements that serve as norms, rules, roles, expectations, hierarchies, and regulations. Cognitive elements are the representative and constitutive factors which shape agencies of actors. For example, Späth and Rochracher (2012) describe how energy regime activities, “are coordinated through various rules – not only a regulative/legislative level, but also by cognitive and normative rule sets (paradigms and cognitive frames, values and expectations)” (p.465).

Murphy (2015) finds that, “place is by-and-large taken for granted by transition researchers, understood implicitly as a contiguous site, territory, or spatial container wherein socio-technical systems are located” (p.11). Rather than understanding place’s significant role to, “serve as critical contexts wherein the practices, norms, conventions, rules, etc. associated with socio-technical regimes are situated, and because the actors driving or affected by the development of a socio-technical system carry with them a sense of, feelings about, and/or visions for the development of the place or places where transition is desired” (Murphy 2015, p.11).[12] Murphy (2015) notes, “the study of place and place-making processes can reveal novel insights into the power relations and political processes underlying transition processes, and thus enable transition researchers to better account for the relationalities and context-specific forces determining the pace,

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[11] In part the ‘geography of sustainability transitions’ “captures the distribution of different transition processes across space” (Hansen & Coenen 2015, p.4).

[12] Murphy (2015) uses the term ‘context’ as a relational concept rather than a territorial phenomenon. The concept can frequently be conceptualized as geographical units such as cities or nation-states.

scale, and direction of socio-technical change" (p.11). Murphy (2015) contributes to the geography of sustainability transitions research by examining the socio-spatial context and interaction of anchoring processes as well as on place-making theory to better understand the relational-political power dynamics of transition initiatives. This is done through an analysis of the geographically embedded elements, socio-spatial contexts, and processes.

Hansen and Coenen (2015) suggest the way to examine the geography of sustainability transitions, is through the analysis of particular settings/places where transitions evolve and are embedded while also looking to the spatial relations in terms of geographical connections and interactions within and between places. Hansen and Coenen (2015) identified in their review of geography of sustainable transitions literature that policy and regulations are important pull factors, in particular in areas including energy, climate, and infrastructure. Hansen and Coenen (2015) describe how, "niche formation and formation processes in emergent technologies are contingent on place-dependent factors such as local technological and industrial specialisation, local natural resource endowments, local market formation, urban and regional visions and policies and localised informal institutions" (p.14). They also describe how 'place-specific norms and values' "have important influences on the geographically uneven landscape of sustainability transitions" (Hansen & Coenen 2015, p.7).

An important concept relating to place is place attachment. Place attachment can be understood as, "the bonding that occurs between individuals and their meaningful environments" (Scannell & Gifford 2010, p.289). Giuliana (2002) note that place attachment is both a process of attachment as well as the product of attaching. Place attachment is important for resource development and transitions as these developments occur in places and affect the way that actors and communities relate to these developments. Devine-Wright (2009) draws from literature on place identity and place attachment to draw connections between positive evaluations of technology proposals that were perceived to 'enhance' the distinctiveness or continuity of places that they were emotionally attached to or that people identified with. Van Veelen and Haggett (2016) found that place attachment can be an important motivator for community organisations developing renewable energy projects.

The goegraphic aspect of scale has been somewhat incorporated into the MLP as discussed earlier by STS and innovation studies scholars, with the help of geographers in some cases. Scale has also been discussed specifically around renewable energy and the inherent qualities of renewable energy and technology that lead to certain spatial characteristics of a renwable energy transition. Calvert and Mabee (2014) argue that, "resources cannot be centralized with the same scale and intensity as fossil and fissile energy resources" which therefore for renewable means there is, "a limitation that is magnified where competing land-uses present energy sprawl and therefore scale-up" (p.6). This is in part,

> Because RE [renewable energy] production facilities cannot be centralized in relatively few locations and dislocated 'out of sight, out of mind' as has historically been the case for fossil and fissile energy systems, the integration of RE resources into the fuel mix exposes an increasing number of communities and individuals to energy production and conversion activities. In other words, the boundaries between spaces of energy production and spaces of energy consumption are dissolved through RE development and implementation. (Calvert & Mabee 2014, p.7)

With the increase in the amount of communities and individuals affected by energy production because of the nature of renewables, there is also an increase in the number of siting decisions, adding to the geographic sensitivity of local factors. Calvert and Mabee (2014) describe a problematic aspect of renewable energy in that, "while RE [renewable energy] resource and distribution systems are necessarily localized their supportive social networks, including the capital, knowledge, and technologies that are necessary to realize the transition to RE, are not" (p.10).

Understanding the geographic dynamics involved in renewable energy transitions is particularly important because as Calvert and Mabee (2014) argue, renewable energy is particularly geographically sensitive because renewable energy production is site-specific and site selective. The site-specific nature of renewable energy production means, "that the scale, intensity and timing of energy production are absolutely limited by the physical constraints and primary productivity of a given area – including aspects related to climate, land-cover, and terrain" (Calvert & Mabee 2014, p.12). Renewable energy is site selective because the renewable energy source and infrastructure must meet these 'place-based' initial socio-economic and technical conditions outlined by Calvert and Mabee (2014),

> (a) within a resonable distance of demand and / or;
>
> (b) within a reasonable distance of distribution infrastructure that has the capacity to transport energy products;
>
> (c) politically accepted as designated for such purposes; and
>
> (d) not currently supporting some other (higher) valued activity
>
> (Calvert & Mabee 2014, p.13)

As Calvert and Mabee (2014) note, fossil fuel energy systems such as coal and gas also are influenced by these factors, however, in contrast, coal and gas can be transported before final conversion.

2.4.3. The Bridge

Work primarily by Bridge et al. (2013) connect STS approaches and geographic approaches to sociotechnical transitions studies. Bridge et al. (2013) in contrast suggest that 'geographies' of transitions have two aspects: the distribution of activities related to the transition across space that produce certain patterns, and the interactions and relationships that create connections between spaces.

In order for a new energy system based around these low carbon energy sources to be developed, there will need to be a complete reconfiguration of the current energy system. This reconfiguration will also be geographical because the current carbon intensive system is also geographically embedded to optimize its energy sources, thus the entire landscape will be transformed for a transition to occur. It is difficult to predict what this geographical transformation will look like. However in the UK approximately 50% of energy use is from personal transport and within home use. This is a far more dispersed form of energy consumption compared to energy consumed during economic production. As Bridge et al. (2013) suggest, this distributed aspect of consumption may mean that a more decentralized energy system would be more beneficial for the future as compared to the current large-scale centralised system (Bridge et al. 2013). This spatial aspect highlights why the field of sociotechnical energy transitions will benefit highly from future research that is spatially-constituted (Bridge et al. 2013).

There are key geographical concepts to discussing geographical aspects of sociotechnical transitions. Hodson et al. (2015) notes that there needs to be, "further development of theoretical and conceptual contributions on scale, space and their interrelationships in processes of transition" (p.12). Bridge et al. (2013) provides a starting point for including a spatial perspective in sociotechnical energy transitions research, which is applicable to all transitions research, by defining and discussing geographical concepts (location, landscape, territoriality, spatial differentiation, scaling, spatial embeddedness, and path dependency). The concepts of space, place, and scale were discussed in the previous section (2.4.2 Geographers and Transition Studies). Path dependency and lock-in was also discussed earlier in this chapter (in 2.1.4 Path Dependency and Lock-in). A set of definitions are given for key geographical concepts in relation to the analytical framework presented in Chapter 4 Towards an Analytical Framework which include: place, space, landscape, scale, multi-scalarity, and spatial embeddedness.

Social and geographical change has often accompanied transitions in the past, as has been observed in various fuel and energy conversion technology shifts (Bridge et al. 2013). New geographies are created from transitions in production, working, and living with energy (Bridge et al. 2013). Bridge et al. (2013) successfully illustrates, "how the low-carbon energy transition is fundamentally a *geographical process* that involves reconfiguring current spatial patterns of economic and social activity" (p.331). There is a certain spatiality created by certain types of energy systems such as with the current carbon-intensive system with the way in which it is configured to extract fossil fuels, generate electricity, transport energy, and dispose of waste (Bridge et al. 2013). These systems are embedded in geographies. For example the, "electricity networks not only reflect the uneven geographies of cities but actively reproduce them" (Huber 2015, p.5).

This reproduction of uneven geographies is part of geographical processes. Späth and Rohracher (2012) describe how these conventional energy systems tend to be made up of, “dominant technologies, practices and institutions at a national or even global level framing the way energy is generated and used, there is considerable variation also of “regime structures” at the regional/local level” however, “these variations are smaller in closely coupled infrastructure networks, such as the electricity system” (p.475). The alternative low carbon energy sources are also embedded within geographical settings. Calvert and Mabee (2014) examine the geographraical implications of the renewable energy transition and argue that the, “physical properties or ‘materialities’ of emerging energy resources are at the root of disruptive change to physical and social landscapes, and therefore of social resistance to policy efforts aimed at a sustainable energy future” (p.1).

Spatial considerations and analyses allow for more accurate understandings and explanation to transition processes. In the past focus has been on the temporal aspects of transition (‘causality of time’) rather than on geography of when and what the spatial circumstances were (Bridge et al. 2013; Coenen et al. 2012; Hacking & Eames 2012). Spatial context is not simply the background context as it is often treated in sociotechnical literature (Coenen et al. 2012). Spatial context should play a larger role in identifying and being a part of theory and causal explanation (Coenen et al. 2012). By including geographical approaches in transitions research there is a better understanding of, “the spatial unevenness of transition dynamics, the embeddedness and durability of incumbent regimes/systems, and the multi-scalar constellations of actors, materials, structures, power asymmetries, flows, and relationalities shaping the prospects for, and direction of, socio-technical change” (Murphy 2015, p.3). Without a spatial understanding and incorporation, the literature cannot properly fully understand and assess the conflicts, advantages, and tensions with transitions because they are embedded within certain economic, institutional, social, and cultural territories (Coenen & Truffer 2012). These tensions and conflicts during a sociotechnical transition are in part also because, “places can be “re-made” during a transition – a process that is often fraught with conflict and which may lead to reconfigured power structures, institutions, and positionalities of regime actors” (Murphy 2015, p.11). More research is needed, particularly using case study analyses as noted by Hacking and Eames (2012), to address this gap in the sociotechnical transition literature to incorporate geography. Better understandings in research will have more practical relevance which will more effectively advise policy (Coenen et al. 2012).

2.5. Conclusion

This chapter is the first of two literature review chapters and it discusses the sociotechnical transitions literature relevant to this study. The fields of Science and Technology Studies (STS) and innovation studies are broadly discussed as they relate and feed into sociotechnical transitions research. Sociotechnical transitions literature is described along with more specifically energy transitions literature. This chapter highlights the limited amount of work that has been conducted to connect and integrate geographical concepts and understandings around sociotechnical transitions. This study contributes to this limited area of study by furthering the theory and understandings around geographical aspects of sociotechnical transitions in the subsequent chapters.

Chapter 3.

Resource Peripheries

The ‘periphery’ as Kühn (2015) explains, is a geographical notion, “synonymous with distance to a centre and being situated on the fringes of a city, region or nation” (Kühn 2015, p.367). Peripheries and cores develop over time through complex processes that create core-periphery relationships. These peripheries tend to be characterized as having relatively large amounts of resources where resource making and destruction occur, therefore these areas can be understood as ‘resource peripheries’. The concept of resource peripheries has been implicitly and explicitly applied to a range of settings (Murphy & Smith 2013). Conflict over these resource peripheries occurs as the need for development and external pressures are imposed, at times in the form of large resource extraction project proposals. Energy projects for rural communities can be a source of conflict and also provide benefits (van Veelen & Haggett 2016). There are alternatives to the traditional, large-scale resource extraction projects which can produce more positive relationships between developments and place attachment such as with community land buyouts in Scotland.

This chapter begins by outlining the literature on theory of core-periphery relationships. Next, four key concepts to understand nature and resources for resource peripheries are discussed: resource making, resource curse, and green grabbing. Then there is a section about resource peripheries with a subsection about energy as a resource. This is followed by a summary around the alternatives to dominant forms of development in resource peripheries, such as community-ownership. Lastly, the concepts of sociotechnical transitions and resource peripheries are brought together to lead into the chapter (Chapter 4 Towards an Analytical Framework) which combines them to form a stronger approach to understanding large-scale shifts with respect to society and technology.

3.1. Core-Periphery Relationships

The idea of conceptually categorizing the world into cores and peripheries arose from development studies and as part of dependency theory (Brown et al. 2000). Various aspects of peripherality have been reoccurring themes within economic geography and regional studies for many decades (Crone 2012). Friedmann (1967) developed the 'General Theory of Polarized Development' to encapsulate the processes of development that cause cores and peripheries to be created. The theory connects development processes in the spatial setting by linking, "the theories of social change and territorial organization" (Friedmann 1967, p.4). There are a range of processes Friedmann (1967) identifies as involved including: domination effects by cores (resource extraction from peripheries), information effects (concentrated information), psychological effects (high interaction), modernization effects (centre's values become more liberal), coupling effects (new markets form in centres), and production effects (cost reduction through innovation). Through these processes cores exploit the peripheries through migration or resource exploitation.

Cores can be understood to be cities, regions, or countries and are centres of technological, economic and social innovation. Periphery is, "defined by its relation of dependency to the core" (Friedmann 1967, p.22). Therefore the periphery concept is relational in that, "peripheries only are peripheries in relation to other places designated *centres*" (Brown et al. 2000, p.58). Cores tend to be associated with the urban and periphery the rural however as Smith and Steel (1995) state, "the situation is very complex" (p.53). Together the periphery and core are an integrated spatial system or subsystem. This spatial system, "is integrated through a pattern of authority-dependency relationships that is focused on the dominant core regions" (Friedmann 1967, p.22). Friedmann (1966) argued that core-peripheries develop following a four-stage growth model where: (1) initial towns/regions develop fairly independently; (2) then a town/region begins to dominate, attracting disproportionally larger investment and migration; (3) semi-peripheries develop characterized by smaller cores that begin to develop; and lastly (4) all areas develop to be dependent on each other where capital and people flow between them. This core-periphery relationship where the, "core region dominance of the periphery is the result of earlier innovations that have become legitimized and incorporated into the central authority" (Friedmann 1967, p.22). Conventional models and indicators of core-peripherality have tended to be based on distance-costs with transport and communication infrastructure improvements viewed as a way to improve the disparity between cores and peripheries (Copus 2001). However it is, "the social use of space that gives meaning to the notion of periphery" (Anderson 2000, p.93).

The relationship between periphery and core is, "based on relational social and economic constructs that have changed over time" (Anderson 2000, p.92). Therefore the periphery is a relational concept that is context dependent as well as dynamic in that it has a temporal aspect (Crone 2012). Therefore as time passes, "the role of a periphery within a socio-spatial system may change" (Kühn, 2015, p.369). Therefore peripheries do not necessarily remain peripheries over time as Kühn (2015) describes, "historical research has addressed the different times and paces of development in centres and peripheries; the perception, from the centre, that peripheries are "backward" or "under-developed"" (p.369).

The essential difference between cores and peripheries is spatial although there are characteristics that are often economic and social in nature that are different. A key aspect is the flow of resources as Smith and Steel (1995) describe, "direct flows of matter, energy, and information to the core from the periphery and formulate rules that control land use at the periphery" (p.56). Brown et al. (2000) present a table of the key differences between cores and peripheries (Table 5). Cores tend to be highly populated with a 'high' standard of living and 'high' levels of economic activity (Brown et al. 2000). Peripheries in contrast are sparsely populated with out-migration (population drift from rural areas to urban centres) and low economic activity that tends to be agriculturally or other rural industry based (Brown et al. 2000). Peripheries have also been characterized as having a lack of innovation compared to cores. Peripheries tend to have, "new products, new technologies and new ideas" imported into the periphery rather than developed within which Brown et al. (2000) attribute to being because, "productive and managerial resources are concentrated at the core" (p.10). Transportation costs are also higher in the periphery because of the distance from mass markets and suppliers (Brown et al. 2000). Although Brown et al. (2000)'s table of core and periphery attributes may be overly general, it is useful for giving an overview of common attributes.

Table 5 Brown et al. (2000)'s table of key differences between cores and peripheries (Data Source: Brown et al. 2000, p.9).

Core	**Periphery**
High levels of economic vitality and a diverse economic base	Low levels of economic vitality and dependent on traditional industries
Metropolitan in character. Rising population through in-migration with a relatively young age	More rural and remote – often with high scenic values. Population falling through out-migration, with an ageing structure
Innovative, pioneering and enjoys good information flows	Reliant on imported technologies and ideas, and suffers from poor information flows
Focus of major political, economic and social decisions	Remote from decision making leading to a sense of alienation and lack of power
Good infrastructure and amenities	Poor infrastructure and amenities

Copus (2001) classifies the disadvantages of peripherality into three groups: causal, contingent, and associated (Figure 11). Within causal there is an increased cost from travel and time due to the relative distance to main population and economic activity centers. There is also a lack of external economies of scale due to the rural location. The next group of disadvantages is contingent. These disadvantages are contingent on the first set of elements of disadvantage. These include high service provision cost, and low innovation and entrepreneurship rates. The other group are associated elements which are less directly related to peripherality, including sparse populations, primary industries dependence, poor local and interregional infrastructure, and a 'lack of influence in the wider governance area'.

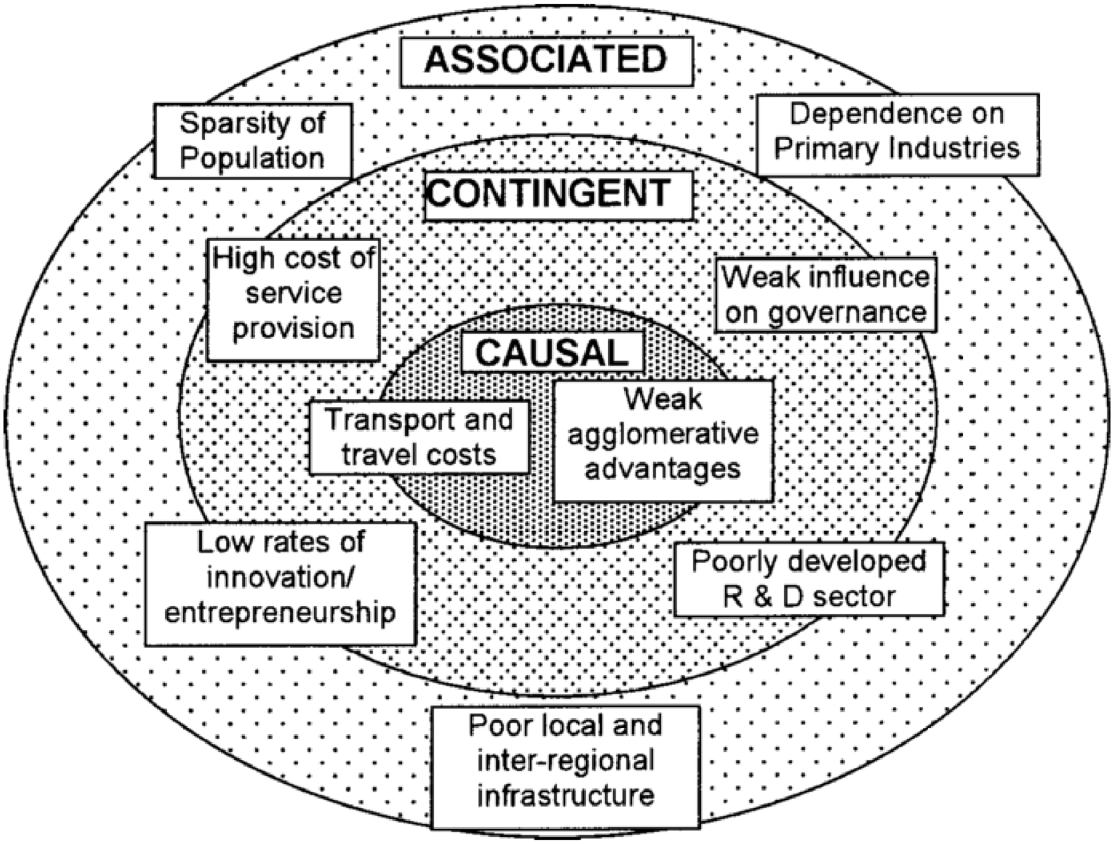

Figure 11 Copus (2001)'s diagram of elements that make up the conventional (spatial) concepts of peripheral disadvantages (Source: Copus 2001, p.540).

The core-periphery relationship is characterized by power because, "it is this unequal or distant relationship with centres of power that marks out a periphery" (Brown et al. 2000, p.2). This spatial aspect of power and core-periphery dynamics is described by Anderson (2000),

> The geographical distribution of society in space creates an unevenness of power. It is therefore argued that society has polarized into cities and a periphery; a periphery that can be characterized as being rural. Consequently key players and the institutions are located in the core. They control and shape resources, and the decisions made about the distribution of these resources are concentrated in these cities. (Anderson 2000, p.93)

Kühn (2015) describes the core-periphery power relationship as,

> Less a spatial fact than a social configuration resting on unequal power relations which lead to uneven spatial development. The political dimension

> is characterized by power in the centre and powerlessness at the periphery. (Kühn 2015, p.375)

However, this is overstated in that the periphery is not in a state of total 'powerlessness'. Cores tend to hold major decision making powers because this is where political and economic institutions are based. This is in contrast to peripheries that have a lack of control over economic and social well-being decisions due to the location of power resulting in, as Brown et al. (2000) describes, peripheries holding, "a sense of alienation, a feeling of governance from afar and a lack of control over their own destiny" (p.9). As Smith and Steel (1995) describe, "core-periphery theory explains processes by which decision making in rural resource-based communities becomes dominated by urban centres" (p.52). Cores are able to some extent, "determine events and conditions in the periphery, and to construct the periphery as the object of the metropolitan imagination" (Brown et al. 2000, p.58). This power dynamic occurs because urban centres hold advantages with respect to synergism[13], centrality[14], and recombination[15] (Smith & Steel 1995).

Smith and Steel (1995) suggest that resource-based communities use coping strategies to deal with these power dynamics include: becoming self-sufficient, creating cartels, promoting community sustainability, changing community identity, and establishing harmony of interests with urban cores. For example, the development of community-owned renewable energy in resource peripheries creates income for communities to become more self-sufficient, promote sustainability, can change community identity, and may provide 'clean' electricity to urban cores contributing to a potential harmony of interests. Another example is that of local food production such as through community gardens. Peripheries may need government to be more involved in economic development promotion than in cores which has been shown by specialist agencies being established for this purpose such as in Scotland and Wales (Brown et al. 2000). Information flow within the core-periphery framework tends to be strongest from

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[13] Synergism is the interaction of multiple (two or more) agents that creates a larger effect overall than the total of the separate effects of each agent.

[14] Centrality is a relative term that refers to location and importance.

[15] Recombination comes from value being added to resources to create products.

the core to the periphery, rather than within the periphery or to the core (Brown et al. 2000). Although there is a large diversity of resource peripheries, these generalizations about resource-based communities can be made because as Hayter et al. (2003) states, resource peripheries are, “collectively distinctive from cores” (p.21).

The process of periphery creation has been termed peripheralization and defined by Kühn (2015) as the, “production of peripheries through social relations and their spatial implications” (Kühn 2015, p.367). There is also a scalar aspect to peripheralization as Kühn (2015) describes, “peripheralization can also be applied to any spatial scale: at the macro scale to developing countries, at the meso scale to non-metropolitan regions or urban regions and on the micro scale to urban neighbourhoods” (p.369). This means that, “processes of peripheralization must be considered not only in relation to centralization, they exist on and between different spatial scales” (Kühn 2015, p.369). Kühn (2015) describes the peripheralization approach as,

- Relational: it is linked to the complementary notion of centralization within a socio-spatial system,
- Process-centred: it is focused on the dynamics of the rise and fall of spaces instead of static locations of remoteness,
- Multidimensional: it is comprised of economic, social and political dimensions (as well as communicative dimensions, which was not discussed),
- Multi-scalar: it is discerned at and between different spatial scales, from global to sub-local and
- Temporal: the role of a periphery may change in long-term perspective and a “de-peripheralization” (or “re-centralization”) is possible.

(Kühn 2015, p.374)

Although it is useful to identify the various aspects of peripheralization, these five aspects identified by Kühn (2015) are difficult to apply. There is a large amount of overlap between the categories, particularly the temporal and process-centred aspects. This study refines these categories by distilling the categories into three: relational, multi-dimensional processes, and multi-scalar.

- **Relational** is the relationships between locations as processes of centralization, peripheralization (or de-peripheralization or re-peripheralization) occur.
- **Multi-dimensional processes** include the economic, social, political, infrastructure, communicative dimensions and processes that occur over time.
- **Multi-scalar** is the multiple scales at and between which the various processes and dynamics can take place (from global to sub-local).

The multi-dimensional processes include factors such as infrastructure and processes such as Science and Technology Studies (STS) concepts of path dependency and lock-in which is neglected in Kühn (2015)'s categories.

The focus of peripheralization is on the processes involved in creating peripheries rather than just the periphery as simply a geographic location. Kühn (2015) shows the differences between peripheralization and periphery shown in Table 6.

Table 6 Kühn (2015)'s comparison of the terms periphery and peripheralization (Data Source: Kühn 2015, p.367).

Periphery	Peripheralization
Pre-given spaces with social implications (fringes, edges, outskirts, borders) *Status: static* • Distance to centres • Remote location • Sparse population *Fields of application: non-urban* • Rural regions • Border regions • Suburban fringes *Conditions for actors: fixed* • Determined by structural deficits • Periphery as 'destiny'	*Social relations with spatial implications* ('production' of peripheries) *Processes: dynamic* • Political • Economic • Social • Communicative *Fields of application: open* • Developing countries • Urban regions and cities • Rural (non-metropolitan) regions • Urban neighbourhoods *Conditions for actors: changeable* • Role of periphery in a system changes • Actor networks matter

It is important to note that a weakness described by Kühn (2015) is that, "the principle of circular causation is often too rigid and clear-cut" which means, "the underlying assumption, that in peripheries everything is in decline due to a loss of migration and investments, neglects the possibility of a "de-peripheralization" or "re-centralization"" (p.371). There is also the process of centralization. Kühn (2015) contrasts the processes of peripheralization and centralization shown in Table 7. Centralization involves the in-migration and control that develops cores.

Table 7 Kühn (2015)'s comparison of the socio-spatial processes of centralization and peripheralization (Data Source: Kühn 2015, p.375).

Processes dimensions	**Centralization**	**Peripheralization**
Economic	*Innovation dynamics* • high-qualified work • growth of employment (business services)	*Lack of innovation* • low-qualified work • decline or employment (decentralization)
Social	*Wealth* • In-migration • Hegemony	*Poverty* • Out-migration • Stigmatization
Political	*Power* • Decision-making and control (autonomy) • Inclusion in networks	*Powerlessness* • Dependency (in decision-making and control) • Exclusion from networks

Anderson (2000) critiques the tendency for the periphery to be defined by negative, value-laden description based notions of distance such as: 'those outer areas', 'the rim', 'the edge or hinterland'. Instead of this approach Anderson (2000) suggests, "the periphery is best understood as a subordinate of the core" (p.92).

Technological advances have affected core-periphery processes. The importance of distance in terms of core-periphery dynamics has been reduced with transport and communication infrastructure improvements as well as the expansion of the service sector with the decline of heavy manufacturing and primary production (Copus 2001). However, Copus (2001) notes that transport and communication upgrades may create a perverse 'pump' effect where the 'natural protection' these places hold due to their poor accessibility is removed resulting in economic activity from these resources to be siphoned away from the periphery to other less peripheral areas with better accessibility and agglomerative advantages. This 'pump' effect is notable with certain renewable energy development projects in the UK as discussed later (in Chapter 10 Analysis). Anderson (2000) also notes the impact of transport and communication developments on core-periphery relationships,

> On the one hand, transport and communication improvements have physically reduced time as an experience of distance. On the other hand, the perceptions of nearness and farness have become less distinct within the 'global village'. Consequently in place of the stable objectification of periphery as distant and remote, interpretations of the periphery have become more subjectified and must now be recognized as more fluid. (Anderson 2000, p.92)

There are processes of (de)peripheralisation, as described by Crone (2012), where an aspect of peripherality is decreased such as through reduction of transportation costs or improvement of infrastructure and accessibility. However, improved infrastructure and transport can lead to increased efficiency of resource extraction that does not reduce aspects of peripherality. Changes can also occur to the type of economy in a periphery, for instance from a manufacturing based economy to a service and knowledge based economy where the factor of physical accessibility is less crucial (Crone 2012).

Core-periphery theory has been frequently applied to both international relations to explain why certain countries have developed relatively faster than others, and to explain resource-based communities that tend to be exploited to supply cores with resources (Smith & Steel 1995). The concept of periphery has been in large part,

> Applied in geography and spatial planning to sparsely populated rural regions, border regions or the suburban fringes of cities. Excluded are larger cities because within this notion cities are defined as centres. (Kühn 2015, p.367)

Past research has focused on cores rather than peripheries particularly within economic geography (Hayter et al. 2003). This focus has created a need for further research on peripheries which has been noted in the literature and this research addresses (Murphy & Smith 2013; Smith & Steel 1995). Much of the forms of renewable energy resources are concentrated within peripheral locations (Murphy & Smith 2013; Hansen & Coenen 2015).

3.2. Nature and Resources

This section outlines the key concepts for understanding nature and resources which are integral parts of resource peripheries. These key concepts discussed are: resource making, resource curse, and green grabbing. Understanding these different aspects of nature and resource are important because as Zimmermann (1951) describes, "resources are the bases of both security and opulence; they are the foundations of power and wealth" (p.3). These concepts have been utilized to understand developing and developed countries (Murphy & Smith 2013). Some of these concepts have emerged from more historical, colonial resource development whereas others are more recent concepts (green grabbing). However, these concepts each are valuable ways to understand the creation and development of resources which are a part of the core-periphery relationship and processes.

3.2.1. Resource Making

Zimmerman (1951) defines resource as not to, "refer to a thing or a substance but to a function which a thing or a substance may perform or to an operation in which it may take part" (p.7). There has been a renewed interest within resource geography to examine the creation of resources as it is, "a concern to understand the political, economic and cultural processes through which particular configurations of socionature become imagined, appropriated and commodified" (Bridge 2010, p.821). Resources are made as described by Zimmerman (1951),

> Resources are not, they become; they are not static but expand and contract in response to human wants and human actions. (Zimmermann 1951, p.15)

Resources are created through cultural, economic, and political work (Hudson 2001).

Zimmerman (1951) describes the three main 'forms of human action' that can be, "determinant as resource makers or destroyers" which are technics (invention), business enterprise, and governmental policy (p.15).[16] There are also other factors that affect resource making described by Zimmerman (1951),

> The resource-creating setup is composed of many parts-invention and technology, business enterprise, market demand, labor, capital equipment, the social and political institutions governing international trade and regulating human relationships both intranationally and internationally. Not only are all these parts essential, but there must be the proper balance between them. (Zimmermann 1951, p.14)

An example given by Zimmerman (1951) of technics or invention playing a central role in resource making is that of rubber from the Amazon. The discovery of vulcanization[17] (in 1839) led to rubber having a range of purposes and the demand for this material 'throughout the world' "governed the process by which "neutral stuff" in the wilds of the Amazon could be converted into the rubber resources of Brazil" (Zimmermann 1951, p.14). This led to the business enterprise aspect of resource making where the Amazon's natural rubber production could not meet international demand and rubber plantations in places such as Sri Lanka, Malay Peninsula, and Indonesia, and new varieties of rubber trees were bred to increase production. The plantations' costs were much lower and eventually out-competed the Amazon's natural rubber production, an example of resource destruction and resource creation. Zimmerman (1951) describes the development of the petroleum industry in Mexico and South America where pre-World War I, Mexico was one of the lead exporters of crude oil but with revolutionary government changes, Venezuela became a main exporter, surpassing Mexico's peak production in less than a twenty year time period. Around this time, Standard Oil (an American oil company) was investing millions of dollars and years to develop their crude oil, however new government rules led to Standard Oil walking away from their investments rather than operate within Bolivia's new rules. This case of crude oil shows, as Zimmerman (1951) states, how "laws, political attitudes, and government policies,

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[16] The concept that the physical environment constrains and determines societal activities, social and economic, is known as environmental determinism. Environmental determinism has been used as a theoretical guide by which to make generalizations. The concept was based on Friedrich Ratzel's theories around nature-culture relationships, and was brought into mainstream academia by Ellen C. Semple (1911) (Frenkel 1992). Environmental determinism has been criticized for conflating the importance of the physical environment over other factors and for being used as a tool to legitimize colonialism (Peet 1985).

[17] This is a chemical process that makes natural rubber more durable by adding sulfur or another equivalent.

along with basic geological and geographical facts, become the strategic factors in determining which oil fields will be converted by foreign capital from useless, "neutral stuff" into the most coveted resource of modern times" (p.16). However, Zimmerman (1951)'s discussion around resource making factors seems to neglect consideration for cultural context.

The creation of resources has been described as the, "relentless 'economization of nature'" because of the continual search for new resources (Bridge 2010, p.822). The process of resource making is fundamentally territorialisation, as it is, "the expression of social power in a geographical form" (Bridge 2010, p.825). This process involves creative-destructive processes which form development that is geographically uneven (Bridge 2010). Consequently this uneven development from the enclosure and commodification of resources is described as reproducing the classic core-periphery dynamics (Bridge 2010).

Bridge (2010) states that within the context of the traditional and new carbon economies researchers have used Marx's concept of primitive accumulation as an analytical device to, "examine how the acts of enclosure and commodification through which carbon economies are constituted are at the same time processes of dispossession: resource making, then, is a form of taking or theft in which the material and cultural attachments of existing resource users are alienated" (p.823-824). The concept of dispossession in relation to resource making and extraction has been termed by Marxist geographer Harvey (2003) to be 'accumulation by dispossession'. This process of accumulation and dispossession through resource making has attracted attention in the literature to explain terms such as 'grabbing' to describe the process, which is connected to the concept of green grabbing discussed further in this chapter (3.2.3 Green Grabbing).

3.2.2. The Resource Curse

The resource curse is a hypothesis used to explain the developmental differences between resource rich and resource poor countries. The term 'resource curse' was first used by Auty (1994) who described this concept as a 'strong recurrent tendency'. This tendency is that countries with large amounts of resources commonly have lower economic growth rates compared to countries with less abundant resources (Auty 1994). The resource curse hypothesis partly attributes this discrepancy in economic growth, as described by Barbier (2005), to be because, “the limits of resource-based development stem from the poor potential for such development in inducing the economy-wide innovation necessary to sustain growth in a small open economy” (p.292). There is also a prevalence where, “natural resource endowments can incite, prolong, and intensify government failure and violent conflict” (Sovacool 2014, p.21). Examples of countries with relatively few exportable resources but high economic growth rates include Japan, Korea, Taiwan, and Singapore (Frankel 2012). Resource rich countries that have not experienced such growth includes many African countries, in the Middle East and Latin America, many of which have large amounts of oil, minerals, and other resources (Frankel 2012). Although this tendency exists there has been research into ways to avoid the negative ‘curse’ aspect of economic development in resource rich countries (Frankel 2012).

Barbier (2015) raises the question, “why should many economies with abundant endowments of land, mineral and fossil fuel resources have such difficulty in sustaining development whereas in past historical eras access to resource abundance was not a “curse” on development efforts?” (p.2). Barbier’s (2015) response is that,

> The answer lies in understanding the changing role of natural resources in the process of economic development in past eras compared to the present. In particular, a key factor appears to be how new supplies, or frontiers, of natural resources are found, exploited and incorporated in various economies. (Barbier 2015, p.2)

Part of this is that a, “critical driving force behind global economic development” to be the, “response of society to the scarcity of key natural resources” (Barbier 2015, p.3). This is because, “increasing scarcity raises the cost of exploiting existing natural resources, and will induce incentives in all economies to innovate and conserve more of these resources” (Barbier 2015, p.3). However, the creation of new resources or frontiers has also been a response to scarcity of resources.

3.2.3. Green Grabbing

A body of literature and debate has surfaced around the neoliberalization of nature and from this a number of terms have surfaced in the literature to describe various forms of resource seizures which include green grabbing, land grabs, water grabs, and resource grabs (Borras et al. 2012; Fairhead et al. 2012; Levidow 2013). Green grabbing is, "the appropriation of land and resources for environmental ends" (Fairhead et al. 2012, p.237). The term was first used by John Vidal, a *Guardian* journalist in 2008, to describe the issues around individuals and charities purchasing large areas of land privately in order to 'protect' them (Vidal 2008). Environmental ends include justifications such as to support biofuel production, biocarbon sequestration, biodiversity conservation, ecotourism, offsets, and ecosystem services. The appropriation can be in the form of changes to access, management, or use through rules and authority alterations that can cause alienating impacts (Fairhead et al. 2012). Green grabbing has come about through new forms of commodification, valuation, and markets (Fairhead et al. 2012). Increasingly nature is being commodified and appropriated by a large range of actors (private actors, national elites, state agencies, etc.) (Fairhead et al. 2012).

Fairhead et al. (2012) argues emerging 'green' markets are causing the emergence of new valuations for different aspects of nature that incentivizes and legitimizes the commodification and appropriation of land and resources. By valuing nature through commodification, the potential for new forms of inequality is created. Issues can also be caused because markets operate based on speculation (Leach et al. 2012). Additionally, the commodification of various parts of nature has taken place in many different forms around the world. For example, the issues around local and national benefits from bioprospecting in Madagascar has been examined by Neimark (2012) who concluded, "participation must include a full share of decision making by rural actors which are accountable to both the Malagasy state and the large bioprospecting actors along the natural products commodity chain" (p.988).

People who live in resource peripheries are vulnerable because of the potential for their resources and lands to be appropriated for economic, larger scale 'greater good', and environmental justifications (Fairhead et al. 2012). An example is that of nuclear superpowers who made the decision to sacrifice the land, lives, and livelihood of inhabitants in rural locations for nuclear activities with the justification that the sacrifice was for the "good of mankind" (Edwards 2011). This justification for mankind is also being used in recent initiatives tied to climate change. Second order nuclear colonialism has been termed by Kuletz (1998) to describe the justification used by national governments and corporations that communities should accept more nuclear testing and toxic waste if they have already done so in the past (Edwards 2011). Various forms of enclosures and territorialisation have been noted by Fairhead et al. (2012) to have occurred based on justifications such as for environmental and economic reasons. For example, the forest reserves and parks instituted by colonial powers in Africa or the state-sponsored plantations in Southeast Asia both significantly affected rural areas, such as through local inhabitant removal or decreasing rights to resources, with the justification for the acts being that they were for the good of the larger region or nation (Fairhead et al. 2012).

The new form of legitimization used to justify land and resource appropriation is the new global green agenda which Fairhead et al. (2012) argues includes: biodiversity reserves, green fuel plantations, and carbon sinks. In these cases the concerns for the livelihoods of the rural people are outweighed by the green agenda and the elites/firms who will profit. This green agenda can be expressed in various ways such as through national targets or certification requirements. For example, a mandatory target was set by the 2009 Renewable Energy Directive (RED) that transport fuel must have a minimum of 10% from renewable energy (biofuels) by 2020 (Levidow 2013). To meet these targets the European Union (EU) would have to outsource for biofuels, largely from the global South. The purpose of the target was to decrease Greenhouse Gas (GHG) emissions while increasing energy security and developing rural areas for biofuel production (Levidow 2013). However, biofuel production has been criticized for causing land grabs, degrading the environment, and increasing food prices (Levidow 2013). This example shows how political targets can result in development that creates core-periphery dynamics. In the case of transnational eco-certification, Vandergeest and Unno (2012) looked at recent shrimp aquaculture in Thailand and argue that eco-certification can act as reinforcements to global relations of longstanding domination that have similarities with colonial-era extraterritorial empire relations.

Huber (2015) notes that the massive green grabbing and land grabs taking place globally make it, “worth making explicit the connections such territorial processes have to the larger energy system and concerns over climate change” (p.8). Considering these examples, are climate change objectives or environmental standards having similar effects on energy production and creating new forms of neo-colonisation? I suggest the concept of ‘land grabbing’ or ‘resource grabbing’ could be applied to the commodification of nature (such as in the case of wind, wave, and tides) with respect to renewable energy.

3.3. Resource Peripheries

Resource peripheries are often rural areas characterized as being ‘full of nature’. Nature can be understood in relation to resources as described by Zimmerman (1951),

> Nature sets the limits within which man can develop his arts to satisfy his wants. Within these limits he is free to select from the myriad possibilities offered by nature those which at a given time and place promise the best results in terms of want satisfaction to return for the humans effort applied thereto. (Zimmermann 1951, p.11)

The concepts of nature are socially shaped and can be sites of struggle where, “power and resistance are exercised” because there are a range of interests linked to nature (e.g. recreation, conservation, livelihoods, etc.) (Mackenzie 2006b, p.385). Lorimer (2000) states that there are many different ‘cultures of nature’ that exist at all spatial scales and they can be reflective, contrasting, and overlapping. Like nature, ‘landscape’ is socially constructed because people view geographic space from a specific viewpoint with a set of values and beliefs which perceive and give social meaning to the landscape (Edwards 2011).

Hayter et al. (2003) states resource peripheries have become ‘deeply contested spaces’, and more so than in cores. This contestation is argued to result from economic geography issues in resource peripheries that are due to resource production, including extraction with minimal processing, occurring within the local area before export. Without processing in the local area, the higher skilled jobs and benefits to the local community are minimized. It also means that peripheries and their resources are areas of large economic investment and sources of profit not solely within the local area. The contention that is caused by these economic geography issues is suggested by Hayter et al. (2003) that they should be, "understood in terms of global-local dynamics that are not experienced or understood in cores and not simply the result of manipulations of global actors upon powerless locals" (p.21). Local opposition can be powerful and result in resource projects not being approved such as in the case of the Barvas Moor wind farm proposal (Munro & Ross 2011; Murphy 2013a; Murphy & Smith 2013) and the Lingerbay superquarry proposal (Black & Conway 1996; Dalby & Mackenzie 1997; Mackenzie 1998; Mackenzie & Dalby 2003), which were both located in Scotland and drew local opposition. Both proposals were eventually turned down by the government. Other resource developments have also faced large amounts of community opposition; however some of these developments were approved and built in spite of the opposition such as with the Bellanaboy gas refinery in Ireland (Garavan 2007; Gilmartin 2009; Murphy 2011; Murphy 2013a). The three examples: the Barvas Moor wind farm proposal, the Lingerbay superquarry proposal, and the Bellanaboy gas refinery are cases examined in more depth in the next part of this literature review.

Conflict can occur when these socially constructed perspectives of nature, resource, and landscapes differ. Some locals often have a sense of identity and rights to the land and these are linked to ownership (Mackenzie et al. 2004; Rennie & Billing 2015). Local residents in these resource peripheries can have a strong sense of place with an associated history and culture which consequently has implications for resource developments. This sense of place is, "re-configured in complex and contingent ways through the re-working of the materiality and meanings of the land and of nature" (Mackenzie 2006b, p.383). New development can cause 'place-protective action' through local opposition because pre-existing emotional attachments and identity of the locals are disrupted and threatened (Devine-Wright 2009). For example, the UK and EU protective designations control land use and therefore impose a certain meaning of 'wilderness' and ‘value’ onto the landscape. These values imposed by the UK and EU can be in opposition to local residents such as crofters who feel they have shown they are sustainable custodians whose livelihoods depend on the land (Mackenzie 2006b). Struggles over the control and shaping of nature and its resources has led to debate over whether resource wealth is a blessing or a curse (such as the concept of resource curse described in 3.2.2 The Resource Curse) as locals often do not have complete control over or gain most of the benefits from development of their local resources (Veltmeyer 2013). Devine-Wright (2009) argues that place attachment does not necessarily result in negative attitudes or opposition from local communities towards development, but can lead to apathy and acceptance. Research often focuses on controversial developments where there is unlikely to be a positive relationship between acceptance of a development and level of place attachment (Devine-Wright 2011a). This research however examines a number or cases ranging from highly controversial to relatively uncontroversial.

Language and terminology play an important role in framing with decision making and justifications relating to resource development. The use of language can be very powerful. For example as stated by Brown et al. (2000), “in modern parlance, to describe something as peripheral is often to dismiss it as unimportant, of no interest to the majority and of no significance to world events (Brown et al. 2000, p.1). Therefore, “to be peripheral is to be marginalized, to lack power and influence and it carries social, political and economic implications” (Brown et al. 2000, p.1). Certain terms have associated meanings or colonial characterizations. Edwards (2011) explores use of the terms remote, sparse, and empty, in the context of justifying nuclear testing in certain rural locations. Colonial powers often consider remote to be in relativity to them and the term is linked to entitlement and racism. Sparsely populated is a phrase frequently considered from a utilitarian approach[18] to justify benefits for the masses and negatives on the few. This phrase can be problematic because it implies the “sparse” area with few people has lower value simply because there are a lesser number of people. This justification based on population density is often used by those in powerful positions

[18] The utilitarian approach is based on political theory and is an ethical stance. This approach is used to prioritize certain groups or individuals. For example the goal or what is considered ‘best’ can be what favours ‘the greatest number of people’ or ‘the most powerful entities’ or the ‘greatest number of species’.

instead of the subjects in the sparsely populated areas themselves. Lastly, the term empty implies nothing exists and ignores what is present, in a sense erasing the existence and any value of what is present. By erasing inhabitants through shared cultural understandings it is impossible to consider the interests of those inhabitants. Murphy (2013a) emphasizes the importance of language as well as history and culture in conflicts over large rural resource extraction projects. Poetry has also been used to aid in understanding and capturing the sense of place to take into account history, culture, and place (Hunter 1995; Mackenzie 1998; Mackenzie 2006b; Murphy 2013a). It is important to be conscious of this power of language in the way in which issues around resource development are framed in peripheries.

3.3.1. Energy as a Resource

There are many types of resources with energy being a particularly central resource for many economies. Energy like other resources can be understood as "inherently a political resource" (Calvert 2015, p.7). As such, Calvert (2015) describes energy as a: physical entity, social relation, primary mediator, and being non-uniform over space,

> a. a physical entity that is derived from natural processes and transformed through physical systems, and therefore partly the domain of the 'physical geographer';
>
> b. a social relation to the extent that physical entities are socially constructed as energy resources through political-economic and cultural processes but also a primary agent in the spatialization of social activities, and therefore partly the domain of the 'human geographer';
>
> c. the primary mediator of our relationship with the enviroment and therefore partly the domain of the 'nature-society' or 'human-environment' geographer; and
>
> d. non-uniform over space and made accessible or not by site-level conditions and therefore partly the domain of the 'GIScientist' and 'cartographer'.
>
> (Calvert 2015, p.4–5)

Resources, such as energy resources, have geographies.[19] Energy has a physical distrubtion over space and as Calvert (2015) states, “physical energy flows and social energy demands are co-productive of socio-spatial relations” (p.1). Renewable energy systems can be understood as either transboundary (including solar and water) or fugitive (for example wind). A fugitive resource is, “when it travels unpredictably through space and therefore does not lend itself well to stationary uses or to the fixed delineations of space upon which conventional political-economic systems and socioeconomic institutions (e.g., sovereignty and private property) are based” and, “therefore require careful integration into legal systems surrounding resource management” (Calvert & Mabee 2014, p.20). Transboundary resources, “also cross jurisdictional lines and are not fixed in place, but their travel is relatively predictable in both time and space” (Calvert & Mabee 2014, p.20–21). In contrast fossil and fissile energy resources are spatially fixed. The fugitive and transbourndary nature of renewable energy resources, described by Calvert and Mabee (2014), the “absolute limitations on our ability to decentralize energy systems within complex built environments” (p.21) and, “compounds existing concerns related to resource access” (p.22). These resource attributes have important implications in the way that they can be developed.

3.4. Alternative Types of Resource Development

As global development pressures continue, local initiatives of alternative approaches are emerging that try to address the negative and positive aspects of large resource extraction projects and issues associated with being a resource periphery. In Scotland some of these local initiatives have taken the form of community land buyouts (Mackenzie 2006a; Mackenzie 2006b). The 2003 Land Reform Act of Scotland established the Community Right to Buy so that resident communities can own and manage crofting estates. The main significance of this Act identified by Rennie and Billing (2015) is in legal terms, “that the land-owning rights are transferred from a private owner to a non-profit-distributing company, owned by the community and

[19] Calvert (2015) argues that “while ‘energy geography’ is arguably a pragmatic shorthand with which to communicate to the broader energy studies community, geographical studies of energy have expanded in scope and theoretical pluarlity so that ‘energy geographies’ is a more appropriate label” (p.1).

managed by the democratic election by members of that community" (p.37). Mackenzie (2006b; 2004) argues community-ownership and management is an alternative to the dominant assumption that privatization and enclosure are the means for progress particularly in 'peripheral areas'. This can be seen with community land buyouts which are local movements that create the opportunity for different forms and approaches to development as compared to the more traditional large-scale, private resource extraction projects. Resource extraction benefits tend to flow to the owner of the resource with minimal spin off benefits to surrounding areas. Rennie and Billing (2015) describe the importance of control over resources for community vitality,

> A major issue in the pursuit of sustainable development for rural communities has been the need to secure a measure of resilience to unwanted change, which is often externally driven. This resilience has been sought through utilising the human and natural resources of the area in a manner that sensitively exploits the ability of these resources to adapt to and benefit from change. (Rennie & Billing 2015, p.36)

Mackenzie (2006a) states that community land buyouts are, "visible evidence of a place-based movement in the Highlands and Islands antithetical to dominant discourses of globalisation" (p.579). A number of community land buyouts have taken place in Scotland such as on North Harris, North Lewis, Bhaltos, Eigg, Knoydart, and Gigha (Mackenzie et al. 2004; Mackenzie 2006a; Smith et al. 2016). This community-ownership results in direct management by community that allows control for different forms of development to occur. For example, these communities can take advantage of their local resources such as with the development of renewable energy. As Huber (2015) describes, "energy extraction is often central to the production of narratives of nationalism and belonging – and it is these narratives that often rationalize local geographies of dispossession and environmental destruction" (p.4). The Isle of Eigg in the Inner Hebrides of Scotland is an example of an island with a 'renewables grid', started in 2008 and owned by the community, which is powered by a combination of wind, hydro, and photovoltaic (PV) energy (Warren & McFadyen 2010). The alternative option of community land buyouts highlights the importance of place in these rural communities and empowers these communities to resist larger landscape pressures.

3.5. Resource Peripheries and Sociotechnical Transitions

Murphy and Smith (2013) connect and extend the concepts of sociotechnical transitions (discussed in the previous chapter, Chapter 2 Sociotechnical Transitions) and resource peripheries (discussed in this chapter) providing an application of the concepts to wind energy projects on the Isle of Lewis in Scotland. The sociotechnical transitions approach has been noted to neglect geographical influences (Coenen et al. 2012; Lawhon & Murphy 2011). The geographical aspects of transitions are important for understanding the process as well as the spatial context, institutional contingencies, and spatial unevenness (Coenen et al. 2012; Coenen & Truffer 2012). Murphy and Smith (2013) suggest that this lack of consideration for geography in the sociotechnical transition's approach can be aided by being combined with the approach of resource peripheries. Murphy and Smith (2013) summarize these two concepts through a comparative table shown below (Table 8).

Table 8 The sociotechnical transition and resource-periphery perspectives (Data Source: Murphy & Smith 2013, p.696).

	Sociotechnical transitions	Resource peripheries
Problem focus	Replacement of one sociotechnical system by another over the long term	Geographies (social, cultural, political, and economic) of resource extraction including costs and benefits
Core concepts	Sociotechnical, transition, landscape, regime, niche	Resource, periphery, core, region, place
Change processes	Existing sociotechnical regimes come under pressure creating opportunities for alternatives which are nurtured in niche spaces	Political-economic processes create new resources whose exploitation can provoke local conflicts and give momentum to alternatives
Key actors	Innovators, policy makers, transition manager	(Transnational) investors and businesses, politicians, communities
Main criticisms	Inattention to issues of power, justice, plurality, and geography	Relatively unsophisticated treatment of technological change
Contribution from the other perspective	Resource periphery can help to explain why niches of particular kinds emerge and how landscape and regime processes interact with particular localities	Sociotechnical transition can help to explain why resources are re-evaluated, how exploitation is configured, and regions/places reproduced or transformed

From Table 8 it is clear that the two approaches of sociotechnical transitions and resource geographies are quite different but complimentary to each other. Resource peripheries are centered on geography because resource extraction occurs in a specific place and focuses on relations and dynamics between peripheries and cores. These resource peripheries are often contested places because of the political-economic processes of resource creation and exploitation (Hayter et al. 2003). In contrast the sociotechnical transitions approach is focused on the overall transition that occurs from one sociotechnical regime to another. To understand this transition process the components are broken down into the different levels: landscape, regime, and niche. The actors involved in the two approaches are different in that sociotechnical transitions are more affected by transition managers and innovators as compared to resource peripheries that are affected by investors, business, and communities. However, both approaches have policy makers or politicians as key actors because policy makers and politicians guide decision making and can also create landscape pressures. Each of these perspectives can contribute to the other, creating a stronger overall approach when combined. The processes that take place in resource peripheries during sociotechnical transitions can be characterized by highly complex transition-periphery dynamics as discussed in Chapter 4 Towards an Analytical Framework.

Chapter 4.

Towards an Analytical Framework

This chapter presents an analytical framework developed during this study through the examination of an empirical case study with the purpose to further the theoretical understandings of sociotechnical transition processes. This analytical framework also addresses the first research question of this study of,

> 1. How can the multilevel perspective (MLP) on sociotechnical transitions be incorporated with the concept of resource periphery to create a more **geographically sensitive model** for understanding new resource peripheries?

This framework brings together the two bodies of literature described in the previous chapters on sociotechnical transitions (Chapter 2) and resource peripheries (Chapter 3). As has been discussed in earlier chapters, these areas of study have remained relatively separate even though the two concepts complement each other. The lack of geographic sensitivity within the sociotechnical transitions framework, which has been noted in the literature (Coenen *et al.* 2012; Hansen and Coenen 2013; Lawhon and Murphy 2011), can be aided by the geographic nature of the core-peripheries model and processes. This chapter proposes extending and refining the sociotechnical transitions model by incorporating core-periphery dynamics and processes as a useful approach to better understand the development of resource peripheries and associated sociotechnical transitions.

This chapter begins by briefly describing the concepts of core-peripheries and the multilevel perspective (MLP), and the need identified for a more geographically sensitive understanding of sociotechnical transitions. Then the key geographic terms utilized in this study to discuss the geography of sociotechnical transitions are discussed. This is followed by an explanation of the connection between the concepts of resource peripheries and sociotechnical transitions as laid out by work by Murphy and Smith (2013). Then the analytical framework developed through this study is presented which focuses on the processes of peripheralization and centralization as part of the sociotechnical transition. The multi-scalar aspect to the framework with the core-periphery relationships and processes are also discussed in this section. This is followed by a short discussion of the challenges and limitations of the framework presented. The chapter finishes with a brief conclusion.

4.1. Sociotechnical Transitions and Resource Peripheries as Separate Concepts

This study proposes a theoretical framework that extends and refines the multilevel perspective (MLP) of sociotechnical transitions by incorporating the geographical concept of resource peripheries and their processes. These areas of study, sociotechnical transitions and resource peripheries, have remained relatively separate in the literature with little discussion regarding the potential of incorporating them. Below is a brief summary of the concepts, however Chapter 2 on sociotechnical transitions and Chapter 3 on resource peripheries present a much more thorough outline of the concepts and relevant literature.

The MLP is one of the main approaches to understanding sociotechnical transitions as discussed in Chapter 2 Sociotechnical Transitions, and it has attracted a significant amount of attention in the literature (Geels 2002; Genus & Coles 2008; Markard & Truffer 2008; Rip & Kemp 1998; Smith & Stirling 2010). The MLP is a middle range theory that has crossovers with a number of ontologies (Geels 2010).[20] Within the MLP there are three levels that are involved in the sociotechnical transition: niche (micro level), regime (meso level), and landscape (macro level). Niches protect and nurture radical innovations from the regime (Geels 2010). Regimes are the dominant practices, rules, infrastructures, technologies, and shared assumptions that guide activities within communities (Rotmans et al. 2001). Landscape is the context and external factors in which interactions and changes take place (Geels 2002). Actors and organisational networks are embedded within the sociotechnical system, in the landscape context and

[20] Geels (2010) identifies seven social science ontologies that the MLP has crossovers with which include: rational choice, evolution theory, structuralism, interpretivism, functionalism, conflict and power struggle, and relationalism.

their perceptions and actions are guided by the regime and rules (Genus & Coles 2008). The three levels are nested, with niches embedded within regimes, and regimes within landscapes (Geels 2002). A sociotechnical transition is the change from one sociotechnical regime to another (Geels & Schot 2007). The transition is the result of developments within and between the three levels that create new alignments (Geels & Schot 2007). Although this framework has been useful within transition studies, there is a need for a better conceptualization of geography, scale, and space in the MLP framework (Lawhon & Murphy 2011). With a better consideration of geography in the MLP the complex dynamics involved with sociotechnical systems and their transitions can be understood. As noted by Hodson et al. (2015), "while focusing on levels of structuration and developments over time, the MLP so far has not been very well equipped to study transitional dynamics as they unfold in space, i.e. in particular places and at different levels of spatial reach" (Hodson et al. 2015, p.2). An amount of research has begun to try and address this need for better understandings of geography in transitions studies, however it is limited (described in Chapter 2.4 Sociotechnical Transitions: What About Geography?).

The core-periphery concept is about geographic relationships and how these change over time. The process of periphery creation has been termed peripheralization (Kühn 2015). Resource peripheries are part of core-periphery relationships. The concept of resource periphery has been implicitly and explicitly applied to a range of settings (Murphy & Smith 2013). Cores are areas that have developed faster than peripheries as cores exploit the peripheries through migration or resource exploitation. Core-periphery theory has been frequently applied to both, international relations to explain why certain countries have developed relatively faster than others, and to resource-based communities that tend to be exploited to supply cores with resources (Smith & Steel 1995). It has also been used to explain the process whereby urban centres become to dominate decision making about rural resource-based communities (Smith & Steel 1995).

Transitions are inherently geographical processes because they occur in particular spaces (Hansen & Coenen 2015). New geographies are also created from transitions in production, working, and living with technology (Bridge et al. 2013). In the past, focus has been on the temporal aspects of transition ('causality of time') rather than on geography of when and what the spatial circumstances were (Bridge et al. 2013; Coenen & Truffer 2012; Hacking & Eames 2012). Increasingly researchers in sociotechnical transitions studies are recognizing that the role of spatial and geographical factors needs to be better addressed in transitions studies (Murphy 2015). There has been an emphasis on space and scale and their role in shaping transition dynamics in recent papers including: Truffer and Coenen (2012), Coenen and Truffer (2012), Coenen et al. (2012), Raven et al. (2012), and Murphy (2015). There has been increased attention on the geographical aspect of transitions as shown in recent publications (Hansen & Coenen 2015; Murphy & Smith 2013; Raven et al. 2012; Coenen & Truffer 2012; Coenen & Truffer 2012) and through recent conferences on sustainability transitions (Hansen & Coenen 2015). As noted by Coenen et al. (2012), spatial context should play a larger role in identifying and being a part of theory and causal explanation. Spatial considerations and analyses allow for more accurate understandings and explanation of the transition processes.

Hansen and Coenen (2015) state that, "few studies in the geography of transitions field suggest alternative frameworks to study sustainability transitions and thus challenge current theorisations of transitions and its geographies" (p.14). However, this study attempts to address this need for alternative frameworks to incorporate geography to examine sociotechnical transitions. This study also addresses the need identified by Hacking and Eames (2012), that more research is needed, particularly using case study analyses, to address this gap in the sociotechnical transition literature to incorporate geography.

4.2. Key Terms

This section outlines a set of key terminology in order to discuss the spatial aspects of sociotechnical transitions. The reason this outline is necessary is because this study is introducing geographical concepts into the sociotechnical transitions framework. There can be confusion because there are geographical terms such as 'landscape' which have a non-spatially explicit meaning within the MLP transitions framework and a very different meaning within geography (Hansen & Coenen 2015). Bridge et al. (2013) defines and discusses a set of geographical concepts as a starting point for including a spatial perspective in sociotechnical energy transitions research, which is applicable to all transitions research. It is important to note that the challenge of introducing geographical concepts into the sociotechnical transitions model is not just terminological but more importantly conceptual. For this study a set of key geographical terms relating to the geographical aspects of the theoretical framework presented in this chapter are described below: (1) *place*, (2) *space*, (3) *landscape*, (4) *scale*, (5) *multi-scalarity*, and (6) *spatial embeddedness*.

(1) *Place* is considered by Murphy (2015) to be a geographical phenomenon with three dimensions: locale, location, and individuals' associated senses or affects.[21] This is in contrast to location which is fixed with a longitude and latitude (Bridge et al. 2013). Murphy (2015) describes place as a 'situated and affect-laden construct' rather than just a site or 'spatial container' where sociotechnical systems are located. Garavan (2007) explains how, "place must not just be understood as merely designating physical, geographical and biological characteristic… the meaning of place also appears to incorporate conceptions of culture, local forms of life and human physical and psychological health" (p.857). Places can be defined at various scales (Hansen & Coenen 2015). Within the sociotechnical perspective, "places serve as crucial contexts wherein the practices, norms, conventions, rules, etc. associated with socio-technical regimes are situated, and because the actors driving or affected by the development of a socio-technical system carry with them a sense of, feelings about, and/or visions for the development of the place or places where transition is desired" (Murphy 2015, p.11).

(2) *Space* has different forms such as physical (e.g. territorially bounded places) and relational, which emerge from interactions between social or economic entities (Raven et al. 2012). Space can be viewed as relational and the, "distance between actors affects how they interact" (Coenen et al. 2012, p.696). Within geography around the discussion of globalisation and space a key theory by Harvey (1989) has been 'time-

[21] Location is a particular physical point as opposed to locale which is where a thing occurs.

space compression' whereby economic activities leads to spatial barriers and distances being reduced. Spatial context is not simply the background context as it is often treated in sociotechnical literature (Coenen et al. 2012). Within the sociotechnical transitions context, space, "has meaning only in relation to the perceptions of actors, and to their interests and strategies" (Raven et al. 2012, p.69).

(3) *Landscape* is both a fixed, unchangeable location (longitude and latitude) as well as a relative place which is highly dynamic (Bridge et al. 2013). It also includes the emotional attachments people form with landscapes and is therefore useful for understanding the social implications of a sociotechnical transition (Bridge et al. 2013). This aspect of emotional attachment overlaps with the concept of place. The concept of landscape is understood differently from a geographic perspective as compared to how the term is used in the MLP. Within the MLP, landscape is one of the three levels which is, "conceptualized as the environment external to the regime" (Coenen et al. 2012, p.971).

(4) *Scale* has been defined by Raven et al. (2012) for the purpose of incorporating it within the MLP as, "the analytical dimension used to measure and study any phenomenon (e.g. time, structure and space)" (p.65). From a sociotechnical transitions perspective spatial scale, "is defined as a territory, and territorial factors and processes are added as an explanatory variable to understanding transitions. Hence, in the case of an absolute spatial scale, territorially bounded institutions, labour forces, resources and so on become part of the explanation of how and why a transition or niche innovation occurs in a particular place and not in another" (Raven et al. 2012, p.70). Scale has many implications for technology including with respect to optimization at certain scales of production. It is also a useful concept for understanding and considering issues of centralization of systems such as with the current energy system, and whether a more de-centralised system would better fit a renewable energy system.

(5) *Multi-scalarity* has been utilized to understand the different scales of phenomenons. Hodson et al. (2015) notes that in sociotechnical transitions, "processes of transition are multi-scalar, with activities simultaneously occurring at multiple scales"

(p.9-10). As described by Raven et al. (2012), "the notion of relative or relational scales offers a means of reframing the levels intrinsic to the MLP as social constructs constituted by organisational and actor relationships that are multi-level" (p.71). Murphy (2015) describes how niches, regimes, and landscapes can all be, "viewed as multi-scalar socio-spatial contexts wherein particular rules, practices, artifacts, identities, agencies, meanings, etc. are embedded or situated" (Murphy 2015, p.5). A multi-scalar approach aids in understanding boundaries and the various levels of scales present (Coenen & Truffer 2012). There has been debate over the ontological tendency towards hierarchy in the relationships between different scales (local, regional, and global) with global holding the most power (Coenen et al. 2012). However, it is at the local scale that the global forces and processes are made and enacted (Coenen et al. 2012). It is important to understand how these scales inter-relate rather than to treat them as a hierarchy (Coenen et al. 2012). Raven et al. (2012) propose a 'multi-scalar MLP' where multi-scalar refers to the scales of time, structure, and space.

(6) *Spatial embeddedness* is discussed by Bridge et al. (2013) to be capital investments, such as infrastructure and the cultures of consumption which are place-based that affect expectations and demand (Bridge et al. 2013). Embeddedness, as Hess (2004) notes within economic geography, "is mostly conceived of as a 'spatial' concept related to the local and regional levels of analysis" (p.165). However, embeddedness is multifaceted with various conceptualizations, such as: spatial embeddedness (Bridge et al. 2013), micronet-macronet[22] (Fletcher & Barrett 2007), social embeddedness[23] (Breton-miller & Miller 2009), temporal embeddedness[24] (Dacin et al. 1999), network

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[22] Micronet-macronet embeddedness conceptualizes embeddedness as having a focal triad of firms that is part of a wider network (Fletcher & Barrett 2007).

[23] Social embeddedness is the, "relationship between an actor's economic behaviour and the social context in which it occurs" (Breton-miller & Miller 2009, p.1171). These relationships are in part because "people live within networks of relationships where information, ideas, passions, and values are shared" (Breton-miller & Miller 2009, p.1176).

[24] Temporal embeddedness examines how processes of embeddedness occur over time. Dacin et al. (1999) highlight the, "importance of viewing sources, mechanisms, and outcomes of embeddedness in broad historical and comparative perspective and the recent contributions of historical/longitudinal studies of embeddedness" (p.340).

embeddedness (Hess 2004), and technological embeddedness[25] (Volkoff et al. 2007). Spatial embeddedness and path dependency are obstacles to sociotechnical transitions. Transitions are, "shaped both by the ways in which socio-technical systems are embedded in particular territorial contexts, and by the multi-scalar relationships linking their heterogeneous elements to actors, materials, and forces situated or emanating from different locations or scales" (Murphy 2015, p.3). The level of embeddedness or lock-in of a system is dependent on various factors such as the amount of infrastructure present and expectations which are culturally influenced. As Bridge et al. (2013) describe, "the spatial diffusion of energy technologies is culturally contingent: how new energy technologies spread across space often depends on how these technologies (and the natural resources upon which they are deployed) are embedded in (national) systems of signification and cultural routines" (p.336).

A body of literature has emerged around the 'disembedding power' of globalization processes (Hess 2004). Disembeddedness can be described, "as a state where social relations are detached from their localized context of interaction" (Hess 2004, p.175). Dacin et al. (1999) describe how globalization, "is regarded as a disembedding process that strips individuals and firms from their local structures and allows for restructuring at a more global level" (p.341). Hess (2004) describes the 'basic mechanisms of disembedding' to be thought to be, "the (modern) creation of symbolic tokens and establishment of expert systems on which actors rely and in which they put their trust" and, "this does not mean that personal relations have lost all their importance in contemporary societies and economic systems, but that personal trust has been 'de-localized' as well" (Hess 2004, p.175). Processes of embeddedness mean that, "embeddedness essentially involves both connection and disconnection" (Dacin et al. 1999, p.341).

[25] Technological embeddedness can be understood as, "the way in which technology introduces a material aspect to organizational elements such as routines, roles, and data" (Volkoff et al. 2007, p.843).

This discussion of the definitions of the key terms is meant to provide a context for how they are used in this study and in the literature whilst recognising that the challenge of linking approaches is not merely one of terminology and definitions.

4.3. Connecting Sociotechnical Transitions and Resource Peripheries

A limited amount of work has been done to connect and extend the concepts of sociotechnical transitions and resource peripheries. Murphy and Smith (2013) have begun this work by providing an application of the concepts to wind energy projects on the Isle of Lewis in Scotland. The sociotechnical transitions approach has been noted to neglect geographical influences (Coenen et al. 2012; Lawhon & Murphy 2011). The geographical aspects of transitions are important for understanding the process as well as the spatial context, institutional contingencies, and spatial unevenness (Coenen et al. 2012; Coenen & Truffer 2012). Murphy and Smith (2013) suggest that this lack of consideration for geography in the sociotechnical transitions approach can be aided by being combined with the approach of resource peripheries. Murphy and Smith (2013) summarize these two concepts through a comparative Table 8 (presented in Chapter 3 Resource Peripheries).

Table 8 (in 3.5 Resource Peripheries and Sociotechnical Transitions) shows that the two approaches of sociotechnical transitions and resource geographies are quite different but complimentary to each other. The geography of resource peripheries is important because resource extraction occurs in a specific location and focuses on processes and dynamics between peripheries and cores. These resource peripheries are often contested places because of the political-economic processes of resource creation and exploitation (Hayter et al. 2003). In contrast the sociotechnical transitions approach is focused on the overall transition that occurs during a shift from one sociotechnical regime to another. To understand this transition process, the components are broken down into the different levels: landscape, regime, and niche. The actors involved in the two approaches are different in that sociotechnical transitions are more affected by transition managers and innovators, as compared to resource peripheries that are more affected by investors, businesses, and communities. However, both approaches have policy makers or politicians as key actors because policy makers and politicians guide decision making and can also create landscape pressures. Each of these perspectives can contribute to the other, creating a stronger overall approach when combined. The processes that constitute resource peripheries during sociotechnical transitions can be characterized as highly complex transition-periphery dynamics. Therefore, this combined approach of sociotechnical transitions and core-periphery dynamics is particularly useful as a critical standpoint for understanding new resource peripheries and associated sociotechnical transitions.

4.4. Proposed Theoretical Framework

The theoretical framework developed during this study introduces the resource peripheries concept to the MLP framework. These concepts complement each other as shown by Murphy and Smith (2013) who connected and extended the concepts of sociotechnical transitions and resource peripheries through their work examining wind energy projects in Scotland. This study furthers this initial work by Murphy and Smith (2013) by proposing a theoretical framework that more thoroughly combines these concepts of sociotechnical transition and resource peripheries by drawing from empirical evidence from a wider set of case study sites. This proposed framework also presents the concept of 'embedded' and 'multi-scalar' periphery-core relationships and processes, as a way to conceptualize and examine the dynamics around resource peripheries within the sociotechnical transition.

4.4.1. Peripheralization and Centralization: Processes as part of the Sociotechnical Transition

This study's conceptual framework is shown in Figure 12 and extends the MLP by incorporating the related processes of peripheralization and centralization within core-peripheries. The diagram shows how the three levels of the MLP (landscape, regime, and niches) are a part of a geography by showing them as part of cores and peripheries. The landscape level encapsulates both the cores and peripheries along with the regimes and niches. The regimes (various systems e.g. energy, food, water, etc.) include some niches and overlap with some of the periphery and part of single or multiple cores. Regimes can also overlap with one another. The niches tend to be located in the periphery in the case of the energy system; however, niches can be present in cores depending on the type of system and technology being examined. An example is that of the Heat and the City Project where research is looking to develop more sustainable ways to heat cities such as through district heating (Hawkey et al. 2016). These areas and boundaries of peripheries and cores change over time as processes of peripheralization and centralization occur as shown in the diagram.

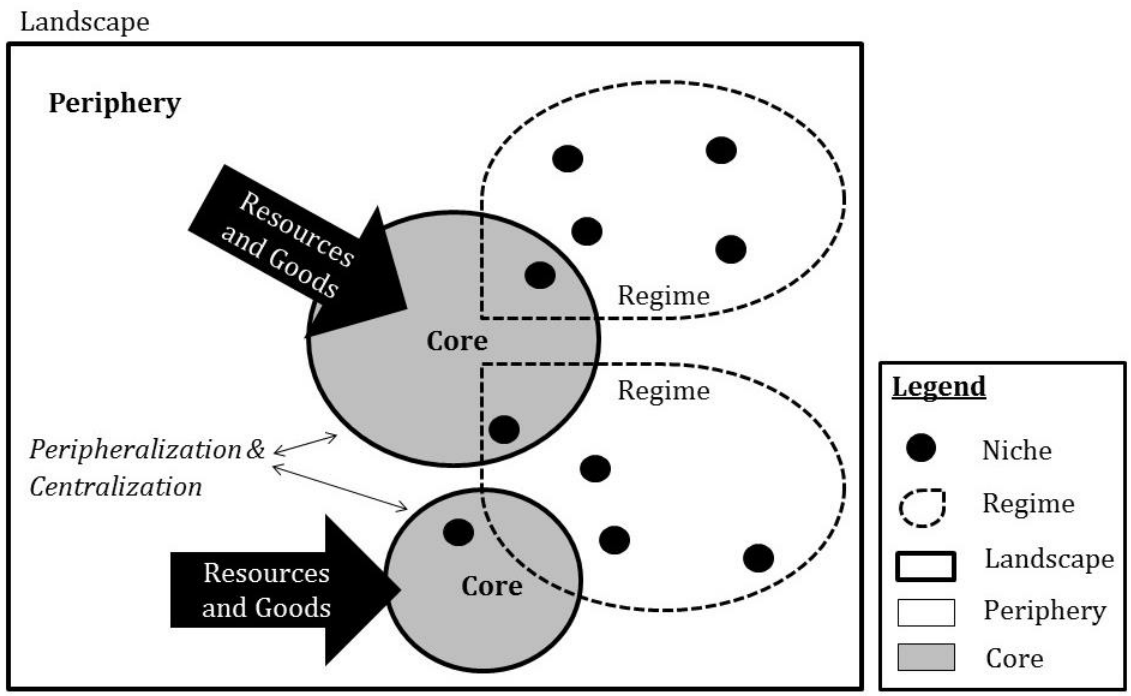

Figure 12 Diagram of the MLP combined with the concept of core-peripheries and peripheralization/centralization.

This diagram (Figure 12) highlights the geography of the basic components (landscape, regime, and niche) of a sociotechnical transition rather than the temporal aspect of the sociotechnical transition except to include the processes of peripheralization and centralization. It is important to note that over time new niches emerge, some niches fail, and others manage to break through to the regime creating sociotechnical transitions as shown in Geels' (2002) model of a sociotechnical transition (Figure 4). These niches are also a part of complex core-periphery dynamics that change over time.

To highlight the sociotechnical transition process over time with the core-periphery concept Geels' (2002) model (Figure 4 in Chapter 2 Sociotechnical Transitions) of a sociotechnical transition is adapted (Figure 13) for this study to incorporate the core-periphery and different transition pathways as processes of peripheralization and centralization occur.

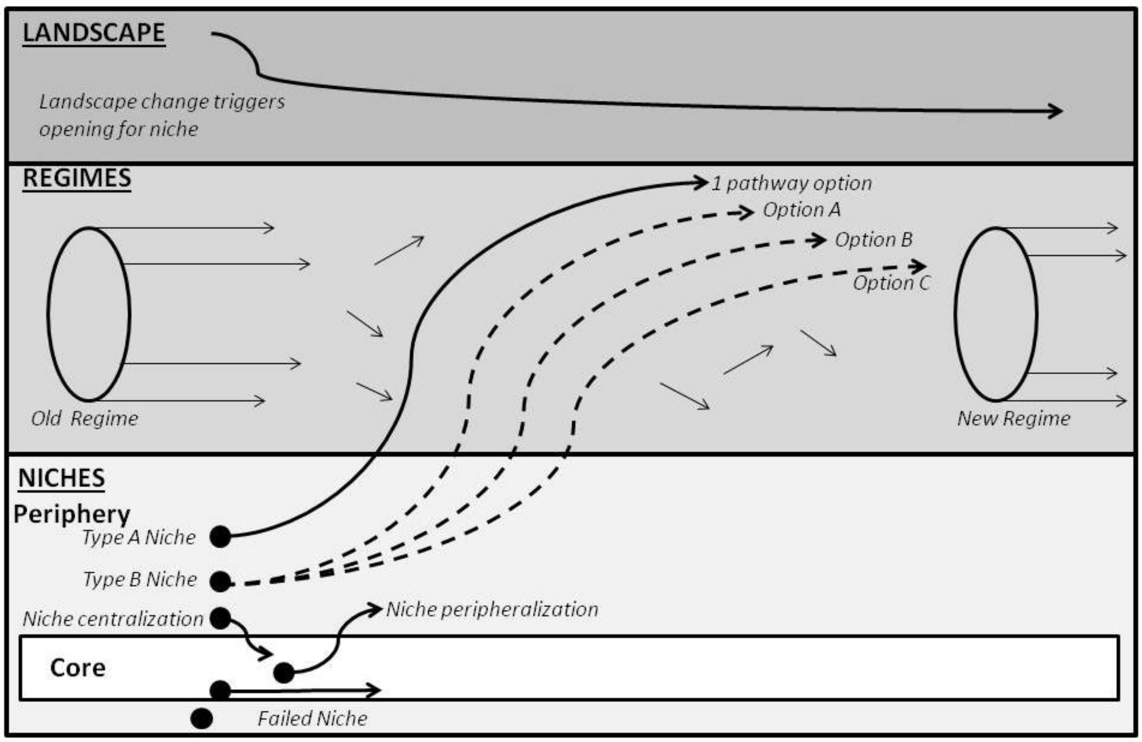

Figure 13 Adapted version for this study of Geels (2002)'s model of a sociotechnical transition to incorporate the core-periphery and different transition pathways.

Figure 13 shows the sociotechnical transition and the arrows represent changes over time and overall interactions between the three levels (landscape, regime, and niche). The processes of a transition are occurring within locations, which can be understood as cores and peripheries. Cores and peripheries develop over time, therefore niches can move from the core to the periphery as part of peripheralization, as well as from periphery to core, through processes of centralization. Niches can have different possible pathways by which they can be adopted into the regime during a sociotechnical transition. However, it depends on the type of technology being adopted because all technologies have political qualities that are either, as according to Winner (1995), 'inherently political technologies' or 'technical arrangements as forms of order' (discussed in detail in 2.1.3 Systems Perspective). The first type involves a technology that's properties mean that it is strongly compatible with certain regime structures, systems, infrastructures, and scales. This is shown as Type A Niche in the diagram with only one pathway option. For the second case, 'technical arrangements as forms of order' mean that a technology is flexible in that it can be adopted in multiple different ways. This is shown as Type B Niche in the diagram and represented by the multiple dotted arrow pathways (Option A, B, and C).

4.4.2. Multi-scalar Core-periphery Relationships

Resource peripheries and sociotechnical transitions can be conceptualized at different scales. As noted by Raven et al. (2012), "concepts of niche, regime and landscape quickly run into complex spatial multi-level realities" (p.75). This has been shown by the sociotechnical transitions literature which has focused on the national scale, followed by global, then urban scales (Raven et al. 2012). Anderson (2000) notes (within a footnote), that the notion of, "sets of core-peripheries can be nested, so that in some contexts peripheral places can be experienced as cores" (p.106). Therefore it follows that the components that make up the MLP (landscape, regime, and niche) can also be multi-scalar. This scale is particularly important when examining the geographic relationships created by cores and peripheries during a sociotechnical transition because there are different relationships present at these different levels. These core-periphery relationships are also relative in that a periphery is only a periphery in relation to a core. These multi-scalar core-periphery relationships are nested within each other with processes of peripheralization and centralization represented by the arrows as shown in Figure 14. Within this diagram, (A) shows the simple, single core-periphery relationship. (B) Is more macro level and shows the first core-periphery as a part of a periphery to another core. (C) Then shows the cores and peripheries from (B) in yet a larger periphery in relation to another core. (D) Is another iteration of this 'zooming out' showing the previous cores and peripheries as another periphery to a core.

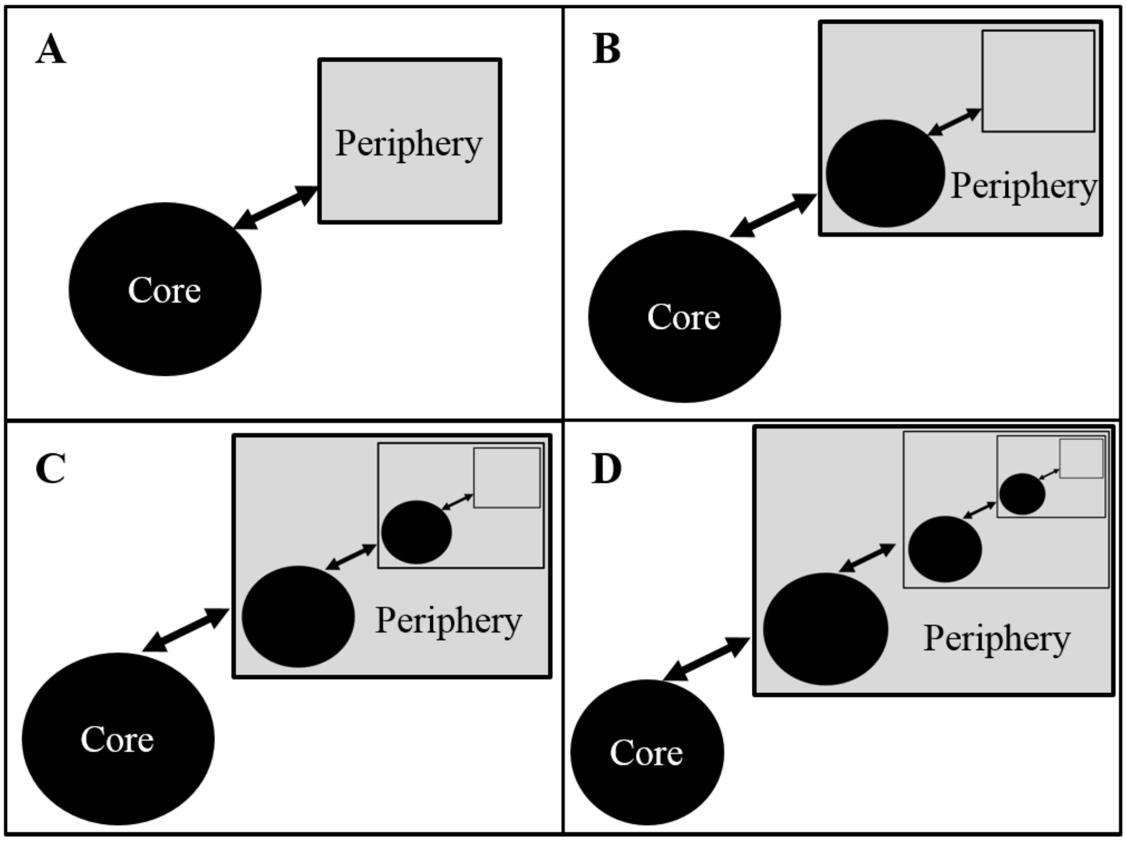

Figure 14 Diagram of nested cores and peripheries with the arrows representing the processes of peripheralization and centralization.

Although Figure 14 shows only a single additional core-periphery encapsulated within a periphery when 'zooming out' from scale to scale, it is important to note that there can be multiple core-peripheries at the same scale encapsulated by a periphery. Niches can be conceptualized as a part of peripheries (and sometimes cores) with relationships to cores (or peripheries) at different scales.

A criticism of the MLP is aided by this multi-scalar perspective of resource peripheries. Raven et al. (2012) criticize the MLP in that the levels tend to be associated with specific territorial boundaries: regime with national, landscape with international, and niches with local or sub-national. The concept presented in this chapter of resource periphery niches that are multi-scalar and ‘nested’ within each other aids in avoiding this association tendency discussed by Raven et al. (2012). It also assists in focusing on the processes, both structural and temporal, occurring within and between the different levels of the MLP. Most importantly by examining these various scales and how niches and peripheries are embedded within one another (Figure 14), it allows for the complex relationship dynamics and sociotechnical transition processes to be more easily uncovered.

4.5. Challenges and Limitations

There are difficulties and limitations with the combined framework presented in this chapter as there are with any framework. There are priorities and trade-offs with any model or framework which inevitably must simplify a system or narrative. Bijker and Law (1992) describe this,

> We are involved, here, in what amounts to a trade-off between following the messy story wherever it leads us on the one hand, and trying to extract, develop, or impose more general models of the course, is that if any description is a simplification—something that we all have to come to terms with when we start to write—then a relatively well-structured model represents a further echelon of simplification. Thus a model or a theory, whatever its form, is a kind of statement of priorities: in effect it rests on a bet that for certain purposes some phenomena are more important than others. It simplifies down to what it takes to be the essentials. And whether or not it is a satisfactory simplification, or indeed an over-simplification, is a matter of judgment and, in the last instance, a matter of personal or disciplinary taste. (Bijker & Law 1992, p.7)

More specifically with a framework there are also challenges involved with incorporating concepts from different fields, in this case, human geography and innovation studies/STS, more specifically core-periphery and transitions research. Hansen and Coenen (2015) describe this challenge due to, “conceptualisations of space and place may create considerable ambiguity when imported from its origins in geographical thought into a sustainability transitions framework” (Hansen & Coenen 2015, p.3). Therefore it is important that it is made clear how the geographical concepts are being conceptualized within the context of where they are being incorporated as this study does with the thorough literature reviews and discussion in this chapter. There are also difficulties when combining approaches. As observed by Hansen and Coenen (2015) the emerging research on the geography of sustainability transitions is receiving attention from a range of fields with different approaches. They state that this has advantages and disadvantages; with positives being that cognitive lock-in is avoided. However, haphazard or fuzzy conceptualisations can result from ‘external’ ideas being imported and translated (Hansen & Coenen 2015). There can also be confusion over dissimilar meanings to similar terms or vice versa (Hansen & Coenen 2015). This issue of terms holding various meanings is one of the difficulties examining the geographical aspects of the MLP because of terms such as ‘landscape’, which within the transitions literature is not spatially explicit, but can be interpreted as holding very different meaning within geography. This is addressed earlier in this chapter by outlining a set of key terminology in order to discuss the spatial aspects of sociotechnical transitions in 4.2 Key Terms. It is also important to note the difficulties of applying a heuristic device as described by Smith (2007) that,

> Whilst this multi-level model has heuristic value, in practice niche-regime distinctions are rarely so clear cut. Distinctions soon break down, as socio-technical components, but not entire alternative practices, translate from niches into regimes and components of each appear in the other. (Smith 2007, p.4)

However, by creating a more nuanced version of the MLP such as presented in this chapter with the multi-scalar and nested levels, this helps unpack the MLP levels. It is clear that there are challenges and limitations to combining frameworks; however, there can also be great benefits when done appropriately with consideration of the weaknesses and benefits.

4.6. Conclusion

The theoretical framework presented in this chapter is a more geographically sensitive conceptualization of the MLP and sociotechnical transition. It was developed through the study of empirical case studies which are discussed more thoroughly in Chapters 7, 8, and 9. The framework builds from initial work by Murphy and Smith (2013) who initially connected and extended the concepts of resource peripheries and sociotechnical transitions. This theoretical framework is complemented by the concept presented in this chapter that resource peripheries and sociotechnical transitions are multi-scalar and ‘nested’ within each other and that this perspective is a way to examine the relationships present at the various scales. A set of geographical terms are also laid out in this chapter as a means to avoid confusion over the potential various meanings of certain terms which can be an issue with interdisciplinary research. The analytical framework presented in this chapter is applied to the case study sites in 10.1 Analytical Framework.

Chapter 5. Methods

This chapter outlines and explains the methods and rationale in this study to address the objective and research questions described in this chapter. An initial literature review was conducted focusing on two main bodies of literature: sociotechnical transitions (Chapter 2) and resource peripheries (Chapter 3). The literature review aided in the development of an analytical framework produced from this study outlined in Chapter 4 Towards an Analytical Framework. This study utilized qualitative methods in combination with a case study approach. The three cases were chosen based on a range of factors in order to obtain a diversity of detailed data on renewable energy development in Scotland. Semi-structured interviews with key informants were the primary form of data collection for these cases and for renewable energy policy and industry for more contextual information to frame the cases within the larger landscape and regime. This data was analysed as described in this chapter and the results are presented in Chapter 10 Analysis.

This chapter begins by describing the research objectives and questions of this study. This is followed by an outline of the research design and rationale which included: a qualitative case study approach, case study selection, and semi-structured interviews. The data collection and analysis process is then described. The limitations of this study and its research methods are outlined at the end of this chapter.

5.1. Research Objective and Questions

The overarching aim of this study is to enhance understandings around the geographical aspects of sociotechnical transitions. To address this aim this study addresses a set of objectives. The first objective is to generate a new model that deals with the relationship dynamics and processes of core-peripheries during sociotechnical transitions. The second objective is to identify dynamics and processes that are a part of sociotechnical transitions and core-periphery processes through empirical evidence from the sociotechnical transition toward renewable energy in the energy system focusing on Scotland. A set of research questions were developed to address these objectives.

1. How can the multilevel perspective (MLP) on sociotechnical transitions be incorporated with the concept of resource periphery to create a more **geographically sensitive model** for understanding new resource peripheries?

2. What are the **sociotechnical transition dynamics** during a sociotechnical transition?

3. What are the **core-periphery dynamics** during a sociotechnical transition?

4. How are **sociotechnical transition dynamics** interlinked with **core-periphery dynamics** in the case of Scotland's transition to renewable electricity?

Each of these research questions are addressed in this study. Chapter 4 Analytical Framework addresses the first research question. The second, third, and fourth research question are addressed in the Chapter 10 Analysis and Chapter 11 Discussion.

5.2. Research Design

The research design of this study was based on the study's research objective and questions as well as previous research in the fields of sociotechnical transition studies and resource peripheries. A range of methods have been used to examine sociotechnical transitions and resource peripheries. However, an inductive and normative approach was used in this research as is common in this research area (Shove & Walker 2007; Smith et al. 2010). Sociotechnical transition research also tend to be framed from a systems perspective (Farla et al. 2012). This study also uses a systems approach as it focuses on the whole system (Chapter 6) and parts of the whole system (Chapter 7, 8, 9) of electricity from production, transmission, and storage through a case study approach. The collective case study approach (detailed in next section 5.2.1. Qualitative Case Study Approach) was used in combination with semi-structured interviews because of the ability of these methods to offer explanatory data. The case study approach and the interview method are commonly utilized when examining resource peripheries and sociotechnical transitions as is explained in more depth in the following subsections of this chapter (Mackenzie 1998; Mackenzie et al. 2004; Devine-Wright 2011a; Devine-Wright 2011b; Devine-Wright & Howes 2010; Murphy 2011; Fudge et al. 2015).

5.2.1. Qualitative Case Study Approach

A case study is simply, "the detailed and intensive analysis of a single case" (Bryman 2012, p.66). A case study is the unit of analysis and is most commonly considered to be a location, community, or organization (Bryman 2012). Multiple cases can be used within a single study (Cousin 2005). The purpose is to examine the nature and complexity of a particular case (Stake 1995). The broad aim is to, "explore and depict a setting with a view to advancing understanding" (Cousin 2005, p.421). Case study research differs from other forms of research because it is focused on description, exploration, and creating understandings (Cousin 2005).

The research of case studies can involve either or both quantitative and qualitative methods (Bryman 2012; Cousin 2005). Researchers often use a hypothesis-led inquiry approach to collect data for case studies (Cousin 2005) however, others such as Stake (1995) have suggested alternative approaches including 'issue questions' to guide data collection. Whichever the methods, 'thick description' is a key feature of a case study because of the detail required to achieve the depth of understanding for a case. Thick description is description of the behaviour as well as the context and was originally proposed by Gilbert Ryle and developed by Clifford Geertz (1973). When the case study is written up the aim is to have enough detail that the reader can in a sense share the experience of the researcher as well as the interpretation of the case (Adelman et al. 1980; Stake 1995).

There are a number of advantages of the case study approach over other research designs. The case study method allows for a holistic, in-depth investigation of the nature and complexity of a particular case (Stake 1995). They also allow for a phenomenon or organization to be studied in its 'natural' context or setting (George & Bennett 2005). The level of detail required for thick description for a case study tends to unearth more accurate or complex understandings. These understandings can be around a social phenomenon and are particularly useful for theory building. However the challenge with the case study approach is to find meanings or reasons behind certain processes or findings rather than only location specific information (Tellis 1997).

Case studies have been categorized into different types by various researchers (Stake 1995; Yin 2009). Stake (1995) outlines three types including: collective, instrumental, and intrinsic. Collective involves a group of cases. Instrumental is a case used to understand something beyond just the case study itself. Finally intrinsic is where the researcher has a certain interest in a specific case. Within the instrumental case approach, a case can be a part of a wider phenomenon that is being studied. These case study types are not exclusive and very often a combination of elements from the different types are used. Other case study types exist such as embedded case studies which include embedded units of analysis within each case.

The case study utilized in this study is collective, as defined by Stake (1995) because there is a group of three cases with an additional proxy case.[26] By using multiple cases there is an increase in the explanatory power and thus generalisability from the collected data (Miles & Huberman 1994). The unit of analysis is the case study and the collective cases are subsystem components which include locations, communities, and organisations. This study's case study can also be considered instrumental because the purpose of these cases is to create understandings beyond the cases themselves such as in that a case can be a part of a wider phenomenon that is being studied (Stake 1995). In this study, the wider phenomenon of a sociotechnical transition to renewable energy is being examined. As described by Geels (2011), single case studies are used in most empirical research on sociotechnical transitions and with the application of the MLP. However, this collective case study approach with the MLP is used in this study in order to better examine multiple subsystem components of the electricity system which is complex, focusing on the production, transmission, and storage of electricity. A set of cases rather than a single case is therefore required to examine these components in depth.

The case study approach has been widely used in past research in both the fields of sociotechnical transitions (Foxon et al. 2010; Geels 2002; Murphy & Smith 2013;

[26] The Cruachan case is a proxy for the Coire Glas case. The Cruachan Hydro Scheme is well established in that it has been operational since 1965 and was important in developing the reversible pump storage technology. Therefore it can act as a proxy case for the Coire Glas Hydro Scheme since there was limited information for the proposed Coire Glas Hydro Scheme available because it is still unclear whether the scheme will go ahead.

Smith 2007; Solomon & Krishna 2011; Turnheim & Geels 2012) and core-periphery dynamics (Borras et al. 2012; Edwards 2011; Leach et al. 2012; Murphy & Smith 2013). However, this study is novel in that it utilizes a collective case study approach with a set of cases from three parts of the electricity sociotechnical system: production, transmission, and storage. Sociotechnical systems such as energy networks are large-scale and complex, therefore the case study approach is particularly appropriate because of this approaches ability to examine a complex contemporary phenomenon within its natural context. The first case of the study, North Yell Tidal Scheme, is a niche within the regime and landscape levels as part of the MLP as described more fully in Chapter 2 Sociotechnical Transitions. The second and third cases represent the transmission and storage components of the electricity sociotechnical system. Although the second and third cases are not niches within the MLP; they represent components of the electricity sociotechnical system that are important parts of the overall sociotechnical transition.

The focus of this study is on Scotland, however there are wider influences and systems involved. Therefore, the unit of analysis includes differing levels of jurisdiction including the EU, UK, and Scotland governing authorities as well as the UK market and infrastructure. The unit of analysis is typically a system of action (as opposed to an individual or group of individuals), and the cases are selective with one or two issues being focused in order to understand the system (Tellis 1997). The issues focused on in this study are identified in the research objectives and question (stated in 5.1 Research Objective and Questions). The study also focuses on electricity rather than other forms of energy because the focus of targets and policies thus far have been on electricity even though it is not the greatest contributor to Greenhouse Gas (GHG) emissions (DECC 2014c). This focus is noted by Geels (2014) in that, “electricity production is often seen as the sector where most progress has been made so far, and where there is most scope for further carbon reductions” (p.24).

5.2.2. Case Study Selection

This study uses a collective case study approach with three[27] cases within Scotland. A scoping trip of three weeks was conducted in July 2014 around the periphery of Scotland prior to case study site selection. The purpose was for reconnaissance to collect information to aid in case study site selection and understand the local geographic context for the study. The trip covered the peripheral generation of renewable energy in Scotland and the associated transmission and policy. The trip began and ended in Dumfries (Scotland) covering a number of the Inner and Outer Hebrides (Gigha, Islay, Coll, Tiree, Barra, North Uist, Harris, and Lewis), Orkney (European Marine Energy Centre (EMEC)), and Pitlochry (hydro scheme). Cases were not selected based on a strict process of random 'sampling' but rather a set of criteria (Cousin 2005). The selection of cases were chosen in order to represent the three main parts of the electricity system: production (North Yell Tidal Scheme), transmission (Shetland Interconnector), and storage (Coire Glas and proxy Cruachan). Figure 15 shows how the cases fit within the context of Scotland's electricity system. For each part of the electricity system, cases were selected based on the research questions of this study.

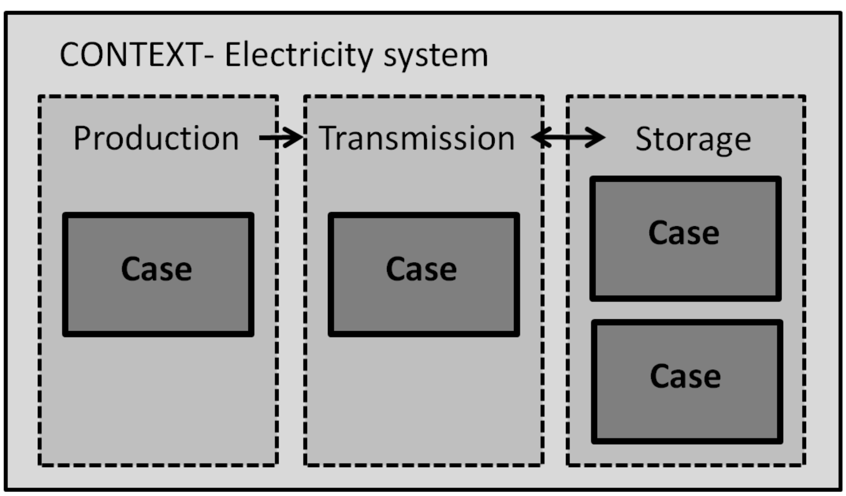

Figure 15 Shows where the cases fit within the electricity system context that makes up the collective case study approach of this study.

[27] Three case sites were selected with an additional fourth case study as a proxy for the case study that was a project proposal with limited information available about it at the time of the study.

The range of cases allows for a larger spread and more representative picture of the renewable energy development in Scotland and therefore of the sociotechnical transition to renewable energy. The cases are located geographically in different parts of the periphery of Scotland: Shetland, between Shetland to mainland Scotland, and mainland Scotland. The projects are each at different stages of development from proposed (Coire Glas and Shetland Interconnector) to fully operational (North Yell Tidal Scheme and Cruachan (proxy for Coire Glas)). By examining these cases of developments that are recently completed or still in the planning phases, it allows for the examination of where the energy transition is moving towards in terms of types of developments. The ownership schemes of the cases also differ with community-ownership to large company ownership being represented. There is a range in size of the projects as well, ranging from 0.4MW to 600MW. The purpose of each project also varies because of their different roles within the electricity system as shown in Figure 16. Production schemes are meant to capture energy and transform it into electricity that can then be connected to a grid system for transport. The transmission of electricity involves transport of electricity from locations of production to locations of consumption. The pumped storage project is an energy storage scheme sometimes described as a ‘renewable battery’ in that it consumes and produces energy on-demand helping deal with the intermittency issues that renewable energy production inevitably creates. The distribution and consumption parts of the system are not examined due to the limited scope and resources of this study.

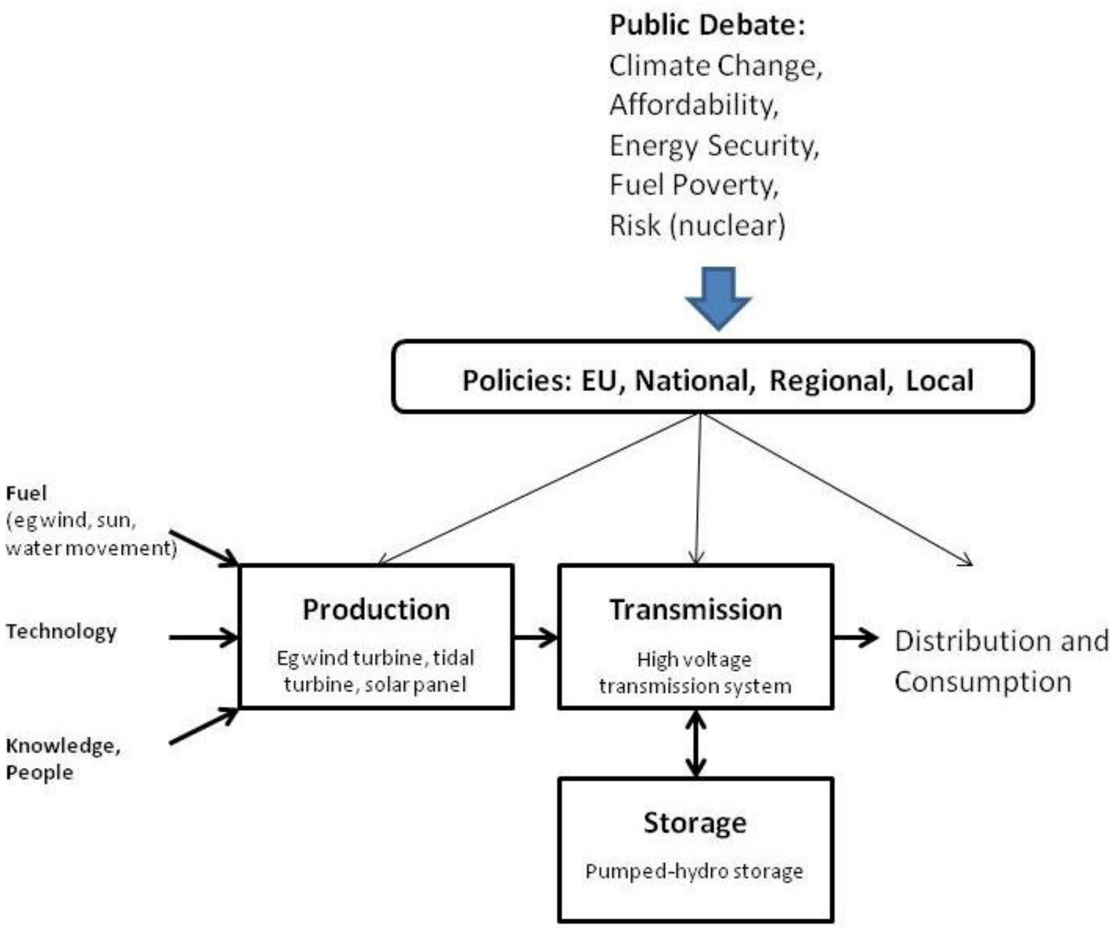

Figure 16 Shows how the cases of this study (production, transmission, and storage) fit into the electricity system from an adapted version of Geels et al.'s (2015) diagram of the sociotechnical electricity system.

Devine-Wright (2011a) has noted that research often focuses on controversial developments where there is often strong local opposition. However, this study attempts to shift this past focus in research by examining both controversial and relatively non-controversial developments in order to have a wider selection of case studies and thus generate understandings that are broader rather than about specific controversial projects. There is a range in the level of controversy between the cases. It is difficult to directly compare the relative level of controversy between the cases. However, the Viking Windfarm on Shetland is framed by developers to require and justify the Shetland interconnector in order to proceed and has been highly controversial as shown through the various court cases and local opposition on Shetland. The other cases that have already been developed, the North Yell Tidal Scheme and the Cruachan hydro station, currently are not facing these same levels of controversy.

A case utilizing onshore or offshore wind turbines is not included directly in this study because of the relatively large amount of research already conducted on wind farms. However, the Viking Windfarm on Shetland is examined in relation to the proposed Shetland Interconnector (second case of this study) because of how those developments are being proposed together. Energy studies journal articles have focused over the past decade and half on wind technology with it being the most studied technology as shown by Sovacool's (2014) review of social science energy research.

North Yell Tidal Project

The North Yell Tidal Project was the first community-owned tidal scheme in the world and is located in the Bluemull Sound in Shetland. The 30kW Nova 30 turbine became operational in the spring of 2014. The project is led and completely owned by the North Yell Development Council (NYDC) in partnership with Nova Innovation, a Leith-based company. The three contributors of funding for the tidal scheme included the Scottish Government's Community and Renewable Energy Scheme (CARES) (£167,763), Shetland Islands Council (£16,990), and NYDC (£1,200) (The Scottish Government 2014e).

The North Yell Tidal Project is the first community-owned tidal scheme and can be understood as the first niche of its kind in the world from a sociotechnical perspective because of the combination of its ownership type and technology. As a community-owned and led development it has likely been a less controversial development as compared to other development proposals on Shetland, for example the Viking Windfarm. Tidal energy is still in the early stages of commercialization with only a handful of commercial tidal turbines in operation in the UK. However, there have recently been additional tidal projects, such as the Shetland Tidal Array (300kW) and the initial phase (Phase 1A) of the Meygen tidal project (6MW) that became operational in 2016 (Meygen 2016).

From a resource periphery perspective the North Yell Tidal Project is in the periphery of Scotland. It is located on the Isle of Yell, north of the mainland Shetland isle. It is also one of the most northerly inhabited islands in the UK. Most of the larger North Isles of Shetland have electricity grids that are connected by subsea cables. However, Shetland is not yet linked through a subsea cable to Orkney or the Scotland mainland. Therefore electricity cannot be exported away from Shetland even though it has a large amount of marine renewable energy development potential. Therefore the renewable energy development on Shetland is significantly limited without a subsea high-voltage direct current (HVDC) interconnector or an alternative way to export or consume power. There are plans for the interconnector to be built with a completion date scheduled for December 2018. However, the cost is high and it is not clear yet whether it will proceed.

Shetland Interconnector, Shetland to mainland Scotland

There are plans for a 600MW subsea high-voltage direct current (HVDC) interconnector to connect the electricity grids between Shetland and the UK mainland. Shetland is a part of the UK electricity market with it being the most substantial non grid-connected electricity network in the UK supplying 15 of Shetland's islands (Scottish and Southern Energy 2010). The interconnector is the responsibility of the grid operator, Scottish Hydro Electric Transmission. The cost of the interconnector is estimated to be £600 million (Bevington 2014). The completion date is scheduled for December 2018.

The interconnector is one mechanism of transport for electricity from Shetland that could allow for large-scale renewable energy projects such as the proposed Viking Windfarm (370MW) that would generate income for the Shetland community through community benefit payments. The Viking Windfarm is a proposal for a 103 turbine wind farm to be built on the central mainland of Shetland by the utility company Scottish and Southern Energy (SSE) (50% stake) and the Shetland community through the Shetland Charitable Trust (45% stake) (McHarg 2015). Permission was granted for the project in 2012 however it has faced judicial review and eventually was taken to the UK's Supreme Court where the appeal was turned down. The 370MW wind farm could produce more electricity than Shetland's population of roughly 22,000 would require; therefore much of the electricity generated would be exported from Shetland (Shetland Islands Council 2009a). The scale of the Viking Windfarm is meant to justify the interconnector because of the current limited local demand for additional power generation on Shetland (Shetland Islands Council 2009a).

The Shetland Interconnector represents the transmission part of the electricity sociotechnical system. Although the interconnector is not a niche itself, it would have large implications for other possible niches on Shetland. The interconnector would drastically alter the constraints on Shetland's electricity grid. Large-scale renewable energy projects such as the Viking Windfarm could be built if there was an interconnector along with space on the interconnector for other renewable energy developments to also export electricity. However, it could also remove some of the niche protective attributes of being an isolated network.

Shetland is located 209km (130mi) north of the Scotland mainland (Shetland Islands Council 2009a). It is part of the resource periphery due to its combined characteristics of its resources (particularly renewable energy as well as others such as oil and gas) as well as its location, being a considerable distance from and having limited links to core centres of consumption (Shetland Islands Council 2009a). If Shetland were to be connected to the National Grid through the subsea cable, it would allow for the export of renewable energy and in a sense increase connectivity of Shetland to the 'core'.

Coire Glas and Cruachan Hydro Schemes

The Coire Glas Hydro Scheme is a 600MW project by Scottish and Southern Energy (SSE) located at Coire Glas. It will be if built, the largest pumped storage scheme in Scotland and estimated to cost £800 million (SEPA 2015). The project has planning approval however, a Final Investment Decision by SSE has not yet been made. This is part due to commercial and regulatory challenges around transmission charging for pumped hydro storage and long-term supportive regulatory framework and public policy (Scottish and Southern Energy 2014). This final decision is not expected to be made until the end of 2017 at the earliest. Objections against the project have been around the 'severe impact' on the landscape and tourism.

The proxy case of Cruachan Hydro Scheme has a capacity of 440MW. Construction work for the scheme was completed in 1965 and its pump technology was the first reversible pump storage hydro system built in the world at the time completed in 1965 (Visit Cruachan 2014). It is operated by Scottish Power and is located on the shores of Loch Awe.[28] Roughly 10% of the water in the reservoir comes from rain water, the remainder is pumped from Loch Awe (Scottish Power 2010).

The Coire Glas Hydro Scheme will be the largest pumped storage scheme in Scotland if built. Due to the irregularity of most renewable energy supplies, there is a need for dispatchable, on-demand energy. Pumped storage can do this by pumping water into the reservoir when there is excess energy on the National Grid and then release reservoir water to produce energy when there is demand from the National Grid. Therefore pumped storage is able to act as a 'green battery' and help with the fluctuating issues of supply other renewable energy sources create. The Cruachan Hydro Scheme is well established in that it has been operational for over 50 years and was important in developing the reversible pump storage technology. Therefore it can act as a proxy case study for the Coire Glas Hydro Scheme since limited information is available because it is still unclear whether the scheme will go ahead. These projects are in a sense part of the larger transition to renewable energy in Scotland because it is necessary to develop more of this type of dispatchable energy source to compensate for the further development of other renewables in Scotland.[29]

Both the Coire Glas and the Cruachan Hydro Schemes are located in rural areas of Scotland, parts of the resource periphery. The Coire Glas Hydro Scheme has been approved even though there were concerns over landscape, visual, and tourism impacts. The John Muir Trust has been particularly vocal about the expected landscape impacts on an area with 'high wild land characteristics' and feel pumped storage is not a renewable

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[28] Cruachan has a dam 396m (1,299ft) above Loch Awe on the slopes of Ben Cruachan. There is a cavern within Ben Cruachan where the four Francis turbines are housed and there is a 1km (0.6mi) road tunnel to access it. There is also a pair of tunnels (penstocks) from the reservoir to the turbines, and into Lock Awe.

[29] Other similar developments occurring in Scotland that are linked to further renewable energy development in the Highlands include the Beauly-Denny powerline upgrade that was recently completed.

energy (John Muir Trust 2012).[30] It also would use renewable energy from other parts of the periphery, creating an energy consumer/producer within the periphery in order to regulate energy on the National Grid for the temporal demand of cores.

5.2.3. Semi-Structured Interviews

Semi-structured interviews allow for multi-perspective analysis which is ideal for examining case studies because relevant groups of actors along with individual actors and the interactions between them are considered (Tellis 1997). The semi-structured nature of this type of interview allows for flexibility as well as structure that enables comparability between interviewees' transcripts (Bryman 2012). For semi-structured key informant interviews, key informants firstly need to be selected. There are two types of key informants: those who conform to their societies' social norms, and those with outlier views and attitudes ('marginal men') (Sjoberg & Nett 1968). Potential key informant interviewees need to be assessed based on the characteristics: their role within the community, knowledge base, willingness to cooperate/participate, good communication skills, level of bias and objective which if there are any biases or objectives they should be made known to the researcher (Marshall 1996). The role within the community is the only characteristic that can be determined prior to the interview. The other four characteristics should still be considered prior to interviews even though they cannot be determined as insights may still be made about the interviewees leading to more productive interviews (Marshall 1996).

Semi-structured interviews tend to be scheduled in advance for a specific location and time. This takes the interview outside of everyday events (DiCicco-Bloom & Crabtree 2006). The relationship between the interviewer and interviewee is particularly important and a positive relationship needs to be established relatively quickly due to the limited length of interviews (DiCicco-Bloom & Crabtree 2006). A set of open-ended questions that are predetermined are usually used along with questions that emerge from

[30] The John Muir Trust argues that pumped hydro storage is not a renewable for of energy because it relies on electricity that could be from renewable or non-renewable sources to pump water into the upper reservoir for storage (John Muir Trust 2012).

the interviewer and interviewee dialogue (DiCicco-Bloom & Crabtree 2006). Interviews commonly take anywhere between thirty minutes to several hours (DiCicco-Bloom & Crabtree 2006). Due to the unstructured aspect of semi-structured interviews and variation of interviewees it can be difficult to predict how long an interview will take, therefore there can be a large amount of variation within a study as detailed in the next section (5.4 Data Collection and Analysis).

The semi-structured interview method is often used in sociotechnical transitions research as well in resource periphery studies. Historical case studies are frequently used in sociotechnical transitions studies which mean secondary data is often also relied on. Resource periphery literature commonly utilizes case studies in combination with interviews. For example, McLahlan (2009) used in-depth interviews to examine a wave energy project in Cornwall, UK to study place and symbolism. Mackenzie et al. (2004) utilized semi-structured interviews along with personal narratives and participant observation in community meetings to research community identity in relation to land with a set of four case studies in peripheral locations. Mackenzie (1998) also used structured and unstructured interviews. Fudge et al. (2015) employs semistructured interviews and the MLP to examine the UK's energy governance and policy. Although interviews is a common method in these fields, other methods are used. For example Devine-Wright (2011b; 2011a) and Devine-Wright and Howes (2010) employed questionnaires with regression analysis and focus groups, however Devine-Wright and Howes (2010) also included in-depth interviews. Relatively new forms of data collection are also emerging as used by Murphy (2011) who conducted a walking narrative method in which he reflects on arguments and lines of thinking that came about from a 1500km (932mi) walk along the west coasts of Ireland and Scotland. Although the methods vary the case study approach and interviews are commonly utilized when examining resource peripheries and sociotechnical transitions (Mackenzie 1998; Mackenzie et al. 2004; Devine-Wright 2011a; Devine-Wright 2011b; Devine-Wright & Howes 2010; Murphy 2011; Fudge et al. 2015).

5.3. Data Collection and Analysis

Semi-structured interviews were the main form of data collection combined with the case study approach. Potential interviewees were identified with a targeted approach. Firstly, key individuals were identified relating to each of the case study sites and in the general electrical energy industry and governing agencies for landscape and regime level interviews within Scotland and the UK. These individuals were identified by examining publicly available information such as websites relating to the renewable energy development. Interviewees were selected based on Marshall's (1996) criteria: their role within the community, knowledge base, willingness to cooperate/participate, good communication skills, level of bias and objectivity. Once initial contacts were made a snowballing sampling method was utilized to help identify other relevant actors that could be potential interviewees. This process was repeated until participants' further interviewee suggestions began to repeat which suggests data saturation was reached. Some contacts were also made through attending a number of industry conferences during 2016 including: International Conference on Ocean Energy (ICOE) (Edinburgh), Scottish Renewables Annual Conference (Edinburgh), and Community and Renewable Energy Scheme (CARES) Conference (Stirling). The attendees at the ICOE were predominantly those involved in the renewables marine industry from around the world. The Scottish Renewables Annual Conference was largely attended by industry officials involved in renewable energy development specifically in Scotland. The CARES Conference was attended by communities interested in or involved with community renewable energy projects relating to the current Scottish Governments CARES program.

A total of 22 interviews were conducted. A number of these interviews were in direct relation to one or more of the case study sites. Particularly interviews about the Shetland Interconnector and the North Yell Tidal Array had a tendency to cover both because of their relation to one another and geographic proximity. Table 9 shows the number of interviews in relation to each case: 7 in relation to the North Yell Tidal project, 8 for the Shetland interconnector, 3 for Coire Glas, and 3 for Cruachan. As well there were 12 interviews at the landscape and regime levels. Many of the interviews related to both a case or multiple cases (particularly with the North Yell Tidal Scheme and the Shetland Interconnector cases) and with the landscape and regime level discussion. Because of the overlaps between interviews the number of interviews shown in Table 9 is larger than the total number of interviews conducted (22). This overlap is shown more clearly in Appendix 1 that lists the type of interviewees in more detail with their interview number. Interview numbers are used throughout this document in order to identify interviewees while maintaining confidentiality. Observational notes were taken during the trips to the case sites. An effort was made to avoid selection bias of interviewees by interviewing a wide range of actors and stakeholders. The range of interviewees included: local authorities, community organizations, renewable energy companies, big six energy suppliers, policy-makers, energy regulators, government departments, government agencies, industry bodies, non-governmental organizations, transmission network operators, and engineers. An interview guide was developed as a flexible framework for these interviews that included a set of open-ended questions that were predetermined and address the study's objective and research questions (Appendix 2). Additional time was given to respondents to discuss if they had particular interest or expertise. Interviewees were also given a Plain Language Statement (Appendix 3) which describes the project and what is expected of participants. All participants also signed a Consent Form prior to their interview (Appendix 4). The length of interviews varied between 30 minutes to an hour and half. These interviews were audio recorded however anonymity was assured. Participants were able to request a summary of the results of the study after the analysis was completed. All data was collected after ethics approval was obtained from the University of Glasgow's College of Social Sciences Research Ethics Committee. Relevant policy documents were also collected and examined as part of the analysis from various policy levels including: council, regional, Scotland, UK, and Europe. A list of these policy documents by policy level are shown in Appendix 5.

Table 9 List of interviews by type and level within the MLP.

MLP Level		Type (local authority, energy company, regional authority, not-for-profit, UK Government, trade association)	Total
Cases (Niche level)	Case 1 North Yell Tidal Scheme	Community Organization (1) Energy Company (3) Regional Authority (3)	7
	Case 2 Shetland Interconnector	Community Organization (1) Energy Company (3) Regional Authority (3) Not-for-profit (1)	8
	Case 3 Coire Glas	Local authority (1) Energy Company (1) Not-for-profit (1)	3
	Case 3 (proxy) Cruachan	Energy Company (1) Regional Authority (1) Not-for-profit (1)	3
Regime and Landscape	Scottish, UK, and EU Levels	Scotland (5) UK (4) EU (3)	12

The analysis approach for this study followed Krueger and Casey's (1994) outline of the steps of analysis. First audio recordings are transcribed. Next there is a stage of familiarization with the data by listening to the recordings and reading over the transcripts and observational notes made during the interviews. During this step major themes are identified and coded through identification of key phrases, ideas, and concepts. An analysis tree of the themes and codes was also developed to aid in structuring the analysis based on the research questions and key concepts in the literature review as show in Table 10. NVIVO was used to analyze the transcripts in this study because of the large amount of data to analyse. Therefore coding was conducted using the NVIVO software and the transcriptions organized through 'nodes' and themes. A theme is considered to be, "patterned responses of meaning within the data set" (Braun & Clarke 2006, p.82). Next the data is sifted through to identify and sort quotes. This is followed by the actual lifting of quotes from their original placement within the transcripts and organizing the quotes into categories. Quotes are compared and contrasted with similar quotes placed together in an effort to reduce and simplify the data (Rabiee

2004). The next stage of analysis is to interpret the organized data. This stage involves looking for the links and meanings between the quotes and data as a whole to examine the differences and similarities as well as draw theories from it (Rabiee 2004). Finally after a draft of the empirical chapters were completed the transcripts were reviewed in order to ensure there were no inconsistencies between the data and the draft chapters as well as that key themes or findings were not missed. Findings from the study were made available to the interviewee participants and communities if requested when the study was completed.

Table 10 Analysis tree of the themes and codes.

Core-Periphery Relationships/ Processes	Peripheralization	Relational	
		Multi-Dimensional	
		Multi-Scalar	
Resource periphery processes	Resource Making		
	Resource Curse		
	Green Grabbing		
Transition Pathways	Path Dependency and Lock-In		
	Technology political quality types (Winner (1995))	Technical arrangements as forms of order	*A technology is flexible in that it can be adopted in multiple different ways.*
		Inherently political technology	*A technology that's properties mean that it is strongly compatible with certain regime structures, systems, infrastructures, and scales.*

5.4. Study Limitations

This study has a variety of limitations primarily relating to the nature of the methods chosen. A challenge of sociotechnical transitions research is that transitions tend to occur over large time frames such as 25 years or more (Farla et al. 2012). This study examines a potential sociotechnical transition in mid-transition (if at all); limiting the insights that can be derived as compared to studying a historical, fully completed transition. However, these insights are particularly important because they will be able to inform this current transition.

This study is limited by its size and scope because a limited number of cases are being examined in order to better understand larger processes. However it was important to keep the study to a manageable size with the resources available for the study. The limited number of cases leads to a common criticism of the case study approach which is the extent to which a single or small number of cases can be representative in order for findings to be derived and applied more generally (Bryman 2012; Tellis 1997). Bassey (1999) suggests that case study research can at best make 'fuzzy generalizations'. Therefore there needs to be an 'ethic of caution' when making generalizations (Bassey 1999). Although there is a need for caution when drawing generalizations from case study research, this approach can still provide valuable insights and generalizations.

In contrast to the issue of 'fuzzy generalizations', Hansen and Coenen (2015) identify a weakness of many geographical analyses of sociotechnical transitions in that they focus on the particular. Hansen and Coenen (2015) argue that, "they celebrate the particular and focus on highly idiosyncratic case stories of specific regions and localities" and that, "it is therefore a challenge for spatial analyses of sustainability transitions to identify and formulate insights with theoretical purchase" (p.3). This study's case study sites are meant to be representative of various parts of the electricity system in Scotland. Although the case study sites are not completely representative of all types of developments; they represent a selection of important types of cases.

Another limitation of case studies is that there is an inevitable selection bias when researchers choose the cases to examine. Practicality of resources or access can limit or determine the cases instead of what would be best from an academic perspective. Researchers also have personal biases and personal perspectives on case studies possibly as insiders or outsiders depending on the case (Cousin 2005). Therefore I tried to be reflective of personal biases and of my position in relation to the case study. As an international student from Canada my position to the case study is as an outsider. This was challenging at times in that I was less familiar with the background and context for some of the case study sites. However, the scoping trip in July 2014 around the periphery of Scotland prior to case study site selection aided me in overcoming this challenge.

There is always the possibility that the number of key informants that were interviewed was too small to gather all the required information and may not represent the views of the majority of the community (Marshall 1996). However this study utilized the snowballing sampling method which in order to determine when the desirable number of interviews had been completed as described in the previous section. Additionally, with this type of study there is the potential of misinterpretation of interviews. Follow up interviews were not conducted for further discussion or clarification. However most interviewees agreed to be recontacted by email if clarification was needed. There is also a temporal constraint because interviews took place between January 2015 and April 2016 and therefore findings are specific to this time period.

The large quantity of data in this study could have made it difficult for the researcher to identify all of the important pieces of information or factors in the cases (Cousin 2005). This can lead to relationships and causations being missed when creating generalizations from data. This is added to by the fact that sociotechnical transitions are inherently complex and it is difficult to identify the key features and dynamics taking place. As pointed out by Markard and Truffer (2008), “innovation and larger transition processes tend to depend on spatial and historical context conditions, which pose a formidable challenge to theory building and research methodologies that aim at generalized empirical findings” (p.596). However, the methods outlined in the previous section (5.3 Data Collection and Analysis) with data analysis through theme identification were followed in order to minimize this risk. Although these study limitations are present, the results of this study offer valuable insights.

Chapter 6.

Existing Energy System

There are UK and Scottish government policies to reduce greenhouse gas (GHG) emissions and invest in renewable energy development. This shift to renewable energy sources involves the creation of new resources by new values being placed on parts of the environment such as wind, tides, and waves, with respect to energy generation which encourages commodification and enclosure of these parts of the environment (Mackenzie 2006b). Scotland has been acknowledged to have significant renewable energy resources with its large amount of onshore and offshore wind, wave, tidal currents, biomass, solar energy, and geothermal energy suitable for capture (Bergmann & Hanley 2012; Toke et al. 2013). Various forms of resource developments have emerged around Scotland as new technologies and policies establish themselves. The sociotechnical system of electricity production and distribution encompasses the technologies for energy production and various factors that affect how they are utilized and developed (Kline 1985). This sociotechnical system is shown by Geels et al.'s (2015) diagram of the electrical sociotechnical system in Chapter 2 Sociotechnical Transitions (Figure 9).

This chapter describes the electricity system focusing on Scotland and renewable energy. It is structured around the multilevel perspective (MLP) framework and draws from Geels (2002). The MLP is operationalized in this chapter as a heuristic device by using the three levels of the MLP as the sections of this chapter: (1) *landscape*, (2) *regime*, and (3) *niche*, to outline recent developments around renewable energy technology and policy in Scotland. The *landscape* level is the external factors and context where interactions and changes occur such as broad political changes, cultural changes, and population demographics (Geels 2002). *Regime* encompasses the dominant practices, rules (such as policies and regulations), and shared assumptions that guide activities (Rotmans et al. 2001). *Niches* are spaces where there are radical innovations because there is protection from the dominant regime for novel arrangements to emerge and survive (Geels 2002; Raven et al. 2008). The literature and theory behind the MLP has been described in more depth in Chapter 2 Sociotechnical Transitions. The MLP approach is a useful structure for this chapter because of the highly complex nature of sociotechnical transitions. The MLP is not the only heuristic device utilized in this chapter; core-peripheries are integrated throughout. The key core-periphery issues noted in this chapter include: geography, scale, ownership, and import-export. The theory and literature around core-peripheries is presented previously in Chapter 3 Resource Peripheries.

6.1. Landscape

There are a range of external factors that form the landscape level of Scotland's electrical sociotechnical system. These factors create a context in which this transition is occurring within that involves a history (temporal aspect) and geography (spatial aspect). An important trait of the landscape context and external factors is that they change relatively slowly over time. The main landscape pressures on the renewable energy electricity system in Scotland are: history, politics, community-ownership of assets, Scottish independence, and public opinion (such as around climate change).

6.1.1. History

Scotland's renewable resources are located throughout the nation which has been significantly shaped by its history and people. This history has had considerable social and cultural implications which Dalglish et al. (2017) identify to be, "historical processes of rural depopulation and the monopolisation of control over the land by a landowning minority; ongoing debate and conflict over questions of who controls and benefits from development of the land; and tensions arising from a drive to protect wild land" (p.2). Major historical events include the de-populating of the land through the Highland Clearances during the 18th and 19th centuries (Lorimer 2000).[31] On a wide scale people were removed from the land, largely in the periphery, along with their ways of life based on traditional land tenancies. Major migration from the Highlands took place to other parts of the peripheries and to cores such as to the coasts, Scottish Lowlands, and

[31] The Highland Clearances were noted for their brutality and extent in that short notice of eviction was often given and entire communities were removed from the land (Hunter 1995).

internationally with people immigrating to locations including North America and Australia. This history of depopulation is significant because as Dalglish et al. (2017) describe, "the past is alive in the conditions it has set for the present" (p.4).

The current population and distribution of cores and peripheries in Scotland has been somewhat influenced by historic events including the Highland Clearances. There is a high density (70% of Scotland's population) that live in the Central Lowlands and relatively low population densities in the Highlands and Islands (Office for National Statistics 2012). This population distribution is noted by Danson and Burnett (2012) to be linked to the 'idea of Scotland' which is, "intimately bound with both visual and cultural aesthetic of peripherality (distanced margins) and remoteness but it is also socio-economically understood as a nation and region of clear differential between its relatively heavily urbanised central belt and the island regions of the north (Orkney and Shetland) and the west (Outer and Inner Hebrides)" (p.5). Scotland's population is roughly 5 million of the UK's 63.7 million population (Office for National Statistics 2012).

The Highland Clearances involved not only people redistribution but also changes to the dominant land-uses and prioritized resources. The Highland Clearances initially meant common lands were enclosed in the shift from small-scale agriculture to sheep farming because sheep became more profitable for land owners than people engaged in agriculture (Hunter 1995). This was followed by a shift to a dominance of deer cultivation for the purpose of what Lorimer (2000) describes as, 'elite blood sports' (stag-hunting) and is also known as 'Balmoralization'. During this time from roughly 1840, it was popular for wealthy aristocrats and industrialists to have estates in the Highlands with a certain version of the Highland tradition and hunting creating a 'colonialism effect'[32] on the Highlands (Toogood 2003). Lorimer (2000) argues that hegemonic control of the land as a resource has been retained in the concentrated patterns of private landownership through 'custodianship' and 'tradition' associated with modern sporting

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[32] There were 'colonialism effects' during the Balmoralization of the Highlands in the sense that many of the impacts were similar to that of colonialism. The similarities include the justification behind the movement which was to make 'improvements' and the effects involved: creating new institutions and systems (clan system to a landlord system), unequal social relations, exploitation, and local ways of life disappearing (with removal of people from the land).

landownership. This land ownership arrangement has implications for resource development in terms of control and benefits.

6.1.2. Politics

Politics are part of the context that shape and influence the electricity system. The Scottish Parliament is a devolved government of the UK and was re-established in 1999.[33] Figure 17 shows the change in political control since 1997 for the UK Government and the devolved administrations. The 2010 UK general election was a shift from the Labour Party to a Conservative-Liberal Democrat Coalition. While (2013) argues that even though the 2010 coalition government came into power with intentions for being the 'greenest government ever', there were cutbacks to subsidies, watered down regulations, resistance to proposed wind farms, and delayed regulation enactment. The UK Government May 2015 election led to a Conservative Party majority, with the Scottish National Party (SNP) winning 56 of the 59 Scottish seats. The SNP was two seats short of an overall majority in the Scottish Parliament in the May 2016 election which followed from a SNP majority administration. The SNP policy shows a vision for the energy sector that involves renewable energy meeting the entire electricity demand of Scotland by 2020 (The Scottish Government 2013a). Also by 2020 the SNP envision Scotland as an electricity exporter as they,

> Intend to be generating twice as much electricity as Scotland needs – just over half of it from renewables, and just under half from other conventional sources. We will be exporting as much electricity as we consume. (Scottish Government 2011, p.17)

The role of nuclear in the 'energy mix' in SNP's policy is, "to phase out existing nuclear power stations as they reach the end of their operating lives" (Scottish Government 2011, p.20). This vision for Scotland's future electricity generation has many implications since this vision requires a large amount of further renewable energy development to meet

[33] Scotland's Parliament was dissolved in 1707 to become part of the Parliament of Great Britain and a referendum held in 1997 voted for it to be re-established (Dalglish et al. 2017)

2020 targets and further development of infrastructure such as interconnectors to directly export electricity.

Year	Westminster	Scotland	Wales	Northern Ireland
1997	Labour Party: majority administration			
1999		Labour and Liberal Democrat Coalition	Labour and Liberal Democrat Coalition	Power-sharing government of local parties with intermittent suspension (4 times)
2001	Labour Party: majority administration			
2003		Labour and Liberal Democrat Coalition	Labour minority government	Assembly suspended
2005	Labour Party: majority administration			
2007		SNP minority government	Labour–Plaid Cymru Coalition	Power-sharing government of local parties
2010	Conservative–Liberal Democrat Coalition			
2011		SNP majority administration	Labour Minority government	Power-sharing government of local parties
2012				
Renewables target:	15% of energy consumption by 2020	100% demand for electricity from renewable energy by 2020	Generating capacity of 7TWhr renewable electricity by 2020	40% of energy by 2020
Installed capacity of renewable energy (MW)*	5880.4	4810.1	856.8	427.6

Figure 17 Political control and renewable energy targets (Source: Ellis et al. 2013, p.400).

The UK Government holds powers over regulation of energy markets, and international negotiation of multilateral environmental agreements (with the European Union (EU) and other countries) including energy and climate change international treaties, while Scotland plays an advisory role on these matters (Bergmann & Hanley 2012). Scotland utilizes domestic legislation, administrative policy, and limited control over funding in order to meet UK set policy and international obligations which are divided through negotiation or proportionally between Scotland and the rest of the UK (Ellis et al. 2013). Much of the renewable resources in the UK are located in Scotland which allows the Scottish Government to negotiate with the UK Government for financial resources in exchange for Scotland's renewable electricity to aid the UK Government in achieving its targets (Toke et al. 2013). Energy related powers that have been devolved to Scotland include energy efficiency, house-building, and renewable energy promotion (The Scottish Government 2014b). Other related devolved powers include: planning, economic development, education, environment, agriculture, forestry, fishing, public transport, and tourism (The Scottish Government 2014b).

Scotland as part of the UK is a member of the European Union (EU). The EU is a political-economic union with 28 member countries.[34] There is also the European Parliament where policies and regulations can be made that apply to all member countries (discussed further in the Regime section of this chapter). However, a referendum (Brexit) was held in the UK in 2016 which voted to leave the EU and since then the UK Government is proceeding with negotiation processes for leaving the EU.

6.1.3. Community-Ownership of Assets

There is a shift by the Scottish Government towards community and local ownership of assets that has been supported through policies, targets, and legislation. This shift has been described by Bryden and Geisler (2007) as the Scottish Highlands becoming 'an epicentre of a land reform' by embracing local community and culture. This community-ownership shift has also been in relation to renewable energy. This is evident with the Scottish Government set targets of 500MW by 2020 of community-owned or locally-owned renewable energy capacity in Scotland being exceeded (The Scottish Government 2013a). Although, this target has been criticized because of the 'locally-owned' inclusion in this target and how this is defined.[35] There are is also a support scheme specifically for community renewable energy, the Community and

[34] The European Union is a trade agreement and political union of 28 countries in Europe including (as of 2016): Austria, Belgium, Bulgaria, Croatia, the Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malt, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the UK.

[35] The definition of 'community' in terms of energy projects has been a source of discussion however Van Veelen and Haggett (2016) note these projects tend to be relatively small (compared to those typical with centralized energy systems), social relations expectation to influence how the development is formed and benefits distributed, and an assumption that these developments are more sensitive to local needs and concerns.

Renewable Energy Scotland (CARES) program (discussed in more depth later in this chapter). Although there is a shift towards community-ownership of renewable energy production in Scotland this is not the case at the UK Government policy level. As Walker (2008) notes, the UK Government policy as of 2008 is not very supportive of community-ownership of energy production in part shown through the lack of support mechanisms (e.g. Feed-In-Tariff (FIT) schemes). The current UK Government is a Conservative government that supports a more free market, non-interference approach than Scotland.

6.1.4. Scottish Independence

There is a movement in Scotland for independence from the UK which has had impacts on energy policy. A referendum to decide whether Scotland should become independent took place in 2014. It resulted in a vote of 55.3% against independence with a turnout of 84.6% (Electoral Commission 2014). The Scottish Independence vote led to commitments from the UK Government for further devolution of powers to Scotland. These new powers mainly relate to taxation, welfare, and elections.

The referendum attracted attention and speculation regarding the implications of an independent Scotland. The Scottish National Party (SNP) launched a ‘Yes’ campaign for independence and produced a government white paper, Scotland’s Future: Your Guide to an Independent Scotland, that was published in 2013. In this white paper there is an emphasis on Scotland’s ‘huge renewable energy potential’. It also acknowledges the geographic and peripheral aspect of this energy in that, “the characteristics of Scotland’s energy generation, supply and use are unique in their geography and peripheral nature – requiring a distinctive regulatory regime” (p.296). Part of this energy vision proposed by the SNP is to provide renewable energy to the rest of the UK as,

> Scotland will continue to participate in the GB-wide market for electricity and gas, reflecting the integrated transmission networks between Scotland and the rest of the UK. There is a common interest in sharing our energy resources with our neighbours. Scotland can continue to provide safe and secure supplies of electricity and gas and can assist the rest of the UK in meeting its renewable energy targets. Our continued participation in a single GB-wide energy market is also in line with the trend for increasing

> integration of energy markets across Europe. (The Scottish Government 2013c, p.295)

Exporting renewable energy is part of this vision of Scotland 'sharing our energy resources' and supports Scotland as a resource periphery in relation to these other countries. However, Toke et al. (2013) notes it is possible that England would have less interest in purchasing renewable energy from an independent Scotland which could limit Scotland's expansion and export of renewable energy.

6.1.5. Public Opinion

A key landscape pressure in relation to a renewable energy transition is the public awareness of climate change (Geels & Schot 2007; Murphy & Smith 2013). There has been recognition that GHG emissions need to be decreased and that sourcing energy from renewable sources is one of the ways to achieve this. Opinion polls in the UK and Europe have shown large public support for renewable energy (Toke 2005). However, there can be local opposition to renewable energy projects of particular kinds that lead to delays and abandoned projects (Toke 2005). Public support for renewable energy has been affected by concerns over energy prices. Geels et al. (2015) describe this change in public support,

> In the autumn of 2013, the cost argument escalated into a full-scale political row over rising consumer bills. Although the debate initially focused on the market dominance and pricing of policies of utilities, the government and energy companies managed to reorient the debate towards green levies and energy-efficiency programs, which were subsequently scrapped, delayed or watered down in exchange for utilities promising to cut energy bills by £50. (Geels et al. 2015, p.14)

Geels et al. (2015) further argue that, "this politicization of the energy bill has eroded green ambitions, and is likely to make future renewable expansion more difficult" (p.14). Recent changes to renewable energy support mechanisms are described in the next section.

6.2. Regime

The regime is composed of various elements: market and industry, infrastructure, science and technology, and policy.[36] These elements are linked together which make them and the regime stable (Geels 2002). The new values that form resources are reinforced and structured by the regime which creates the structure and rules by which markets and institutions operate. Within the regime there are a range of actors, that are located within a geography, including: households, large industrial users, energy supply companies, distribution network operators, transmission system operators, electricity generators, national governments, and regulators (Foxon et al. 2010). The regulatory regime for energy in the UK is shifting with local authorities becoming more involved in energy, as noted by Fudge et al. (2015) who suggests that, "the low carbon agenda in the UK has provided a 'window of opportunity' for some of the more progressive of them, suggesting that local authorities are likely to exert greater influence over the future direction of energy policy in the UK" (p.3). By 'window of opportunity' Fudge et al. (2015) reffers to, "where the role of local government has been able to exert greater influence over energy, within the context of evolving national and international policy frameworks and has consequently become more influential in decision-making on energy and environmental issues" (p.3).

6.2.1. Electricity Market and Industry

The electricity sector in the UK has been liberalized which loosened (not replaced) the technology regimes and is creating an opening for a transition (Markard & Truffer 2006). The market for renewable energy has grown sharply over the past five years (Ellabban et al. 2014). Policy instruments such as the Renewables Obligation (RO) and Feed-In-Tariff (FIT) programs have opened the energy market to renewable energy development and technology that otherwise would not be able to compete with other types of more established energy production. Ofgem is Britain's national regulatory

[36] This list is based on Geels and Schot's (2007) list of regime elements: industry, science, technology, markets and user preferences, culture, and policy.

authority for wholesale energy markets.[37] A wholesale electricity market was created between electricity generators and suppliers within the UK in 2005.[38] This market trading system created a single-price energy market.

The electricity supply industry in the UK is dominated by a number of large power producers connected to the National Grid. These large producers have dominated the energy sector since its privatisation in 1990 (Lockwood 2013). These producers are sometimes referred to as the 'big six' and include: Centrica, E.On UK, EDF Energy, RWE npower, Scottish Power, and SSE (Lockwood 2013).[39] They are also investors in renewable energy development in the UK particularly focusing on wind energy (Lockwood 2013).

The main renewable energy trade organisation in Scotland is Scottish Renewables with its sister organisation RenewableUK covering England and Wales.[40] Cowell et al. (2013) argues that Scottish Renewables offers, "a unified focus for the sector and its relations with government" (p.25) in Scotland which is what Wales has lacked due to limited 'large, domestic energy businesses' and limited resources from RenewableUK. However, these types of industry representative organisations such as RenewableUK can be 'problematic', as described by Strachan et al. (2015), in that, "the main representative bodies for the renewable energy sector… have their agendas dominated by the major companies that make up their main membership" (Strachan et al. 2015, p.105).

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[37] Ofgem is responsible for monitoring, investigating and enforcing, breaches of REMIT which is an EU regulation that provides a regulatory framework for the wholesale energy market and has been in force since 2011 (Ofgem 2015).

[38] The wholesale electricity market was created through The British Electricity Trading and Transmission Arrangements (BETTA) which covers England, Scotland, Wales, and Northern Ireland.

[39] British Gas operates as Scottish Gas in Scotland and is the largest UK domestic energy supplier. Npower is part of the German power company RWE. SSE is a UK company. Scottish Power is part of a Spanish energy company Iberdrola. E.On is part of the German E.On Group. EDF is owned by a subsidiary of the French state-owned EDF Energy Company.

[40] Scottish Renewables is an industry representative body established in 1996 and has over 300 member organizations involved in generation, supply, and distribution of heat, power and other fuels.

Other, smaller electricity producers also exist in the UK including a number of community renewable energy projects.[41] These can take a number of different forms through variations of financial investment and managerial control by communities, cooperatives, community charities, development trusts, and shares (Walker 2008).[42] Walker (2008) identifies the main incentives of community-owned energy generation: local income and regeneration, local approval and planning permission, local control, lower energy costs and reliable supply, ethical and environmental commitment, and land management. There are an increasing number of community energy intermediary organisations creating toolkits and case studies to help share community experiences and knowledge around renewable energy development such as Community Energy Scotland (CES) (Smith et al. 2015).[43] There were 508MWs of locally and community-owned renewable energy capacity reached in 2015 (Energy Saving Trust 2015). Some of these community renewable energy projects have been developed through an initial community land buyout such as on the Isle of Lewis, Isle of Harris, and Isle of Gigha. Land ownership is important because the owner of the land has control over working the wind and other resources (Mackenzie 2006b). Community energy projects face challenges as they are complex projects to undertake involving technical, legal, funding, insurance, permissions, construction, marketing, and regulatory aspects (Smith et al. 2015). The changing renewable energy policies have also been a challenge as community energy groups, "have had to be very nimble, entrepreneurial, and resilient in seizing opportunities amidst a shifting policy landscape" (Smith et al. 2015, p.10). Smith et al.

[41] It is important to note that the term 'community energy' does not always refer to community-owned schemes. It is sometimes used to describe energy projects that involve an outcome with a community element such as "utility projects that provide energy insulation measures to local communities in return for hosting a wind farm" (Smith et al. 2015, p.6).

[42] Cooperatives are made of members who can be local or abroad that have bought shares to finance a project. Community charities are associations that provide or run facilities for the community, often with charitable status. Development trusts have been used to represent community interests through revenue-generation enterprises, particularly in Scotland. Shares of private, commercial projects can be gifted to a local community organization (e.g. a trust) or even in the case of wind farms, turbines can be gifted to the community (as with the Earlsburn wind farm in Scotland).

[43] CES originates from the Highlands and Islands Community Energy Company founded in 2004 as a subsidiary of Highlands and Islands Enterprise (HIE) which evolved into CES in 2008 and became an independent Scottish charity (Walker 2008).

(2015) identifies community energy in the UK as, “an area of rapid growth in grassroots innovation, and where policy interest has recently increased” (p.2).

6.2.2. Infrastructure

Transport of electricity from locations of production to consumption involves a range of infrastructure. It also involves connecting peripheries to cores and this infrastructure acts as a lock-in mechanism that stabilizes the regime (Unruh 2000). The traditional electricity distribution system operate in a ‘passive manner’ in that electricity flows in one direction, from generation, transmission, distribution, to consuming customers with the network and transmission capacity designed for peak demands (Bolton & Foxon 2015).[44] This traditional electricity transmission network predominantly transported electricity from large, fossil fuel power stations located near cores to the less populated peripheries. However, this dominant flow of electricity (resource) is being reversed as renewable energy in these peripheries are being developed and connected to the National Grid to supply electricity to the cores. This has led to more ‘active’ operation approaches of networks such as through smart meters that allow for ‘real time’ collection of energy use data (Bolton & Foxon 2015). This also involves upgrades to the transmission lines.

One of the major transmission upgrades recently completed is the Beauly-Denny power line that is necessary to allow for further development of renewable energy in the Highlands so that the energy can be transported to the Central Lowlands (including Glasgow and Edinburgh) for consumption (Munro & Ross 2011). These upgrades are also needed as the transmission infrastructure is aging as described in the Scottish Government’s (2011), 2020 Routemap for Renewable Energy,

> The electricity transmission network (the grid) in Scotland – as in the rest of the UK – is old and was designed for a different era of cheap power generated close to centres of demand. It is a fact that the best sources of renewable energy is found at the peripheries of the current network, and we

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[44] Distribution can also involve conversion processes including stepping-down voltages or generating Alternating Current (AC) from Direct Current (DC) supplies.

> face a real challenge in building a grid which will allow Scotland to harvest and export its vast resources of clean energy. (Scottish Government 2011, p.41)

In particular the connecting of wind farms which tend to be located in rural and peripheral locations to the National Grid, has, “required new lines, grid reinforcement and back-up capacity (to deal with fluctuating flows)” (Geels et al. 2015, p.20). Ofgem and the National Grid have taken a ‘connect and manage’ approach since 2009 to deal with the issues relating to new wind farms connecting to the grid which involves having the wind farms connect to a local grid first and then followed by wider reinforcements constructed (Geels et al. 2015). This is in contrast to the previous ‘invest then connect’ approach where grid connections led to delays in wind farms receiving connection (Geels et al. 2015).

Interconnectors link parts of the electrical grid system together which also in turn links peripheries to cores in that they allow electricity to flow between them at different scales which is multi-scalar, including: regional, national, and international. Interconnectors are considered a technical way to create a more stable electrical system and to allow for larger amounts of intermittent renewable energy generation to connect to the system. There is also an economic aspect to interconnectors in that they can allow for increased competition and a larger market. The National Grid (2014) supports a vision of a more interconnected electricity system because of these economic aspects, “a greater level of interconnection provides a greater diversity of potential supplies, facilitates competition on the European market and assists the transition to a low carbon energy sector by integrating various renewable sources” (p.1). Interconnectors can link parts of the electricity system within the UK or connect to other countries.

As of 2014 the total UK international electrical interconnection capacity was roughly 4GW (shown in Figure 18) (National Grid 2014). This interconnection capacity is important because it allows for a certain amount of electricity to be directly imported or exported. The UK is a net importer of electricity with 6.2% of electricity supplied in 2015 from imports (DECC 2016). The 4GW UK international capacity is made up of four interconnectors connecting to France (2GW), the Netherlands (1GW), Northern Ireland

(500MW), and Republic of Ireland (500MW) (National Grid 2014).[45] These interconnectors have resource periphery implications, for example a Memorandum of Understanding was signed between the Irish and UK governments in 2013. This created a policy framework for the UK to directly receive electricity through the interconnector and exclusively purchase renewable energy from Ireland's future expanded wind farms to meet their renewable energy targets (Scott & O'Neill 2013). This has come about as Scott and O'Neill (2013) describe, because, "Ireland has "excess" sites with wind energy capacity whereas the UK is now facing vocal opposition to the erection of wind farms in the landscape and may not have sufficient viable sites to achieve its renewable energy target in a cost effective way" (p.419). This situation, with the UK potentially locating unwanted wind turbines in Ireland to meet their renewable energy targets, could be considered a 'resource grab' which is a point further explored in the analysis (Chapter 10 Analysis).[46] The National Grid (2014) outline potential future interconnectors between the UK with: Belgium, Norway, France, Denmark, Iceland, and Ireland (shown in Figure 18).[47] These potential interconnectors would increase export and import capacity which has core-periphery dynamic implications particularly at the international scale.

[45] The four interconnectors are called: IFA, BritNed, Moyle, and East West. IFA interconnects with France by a 70km (44mi) cable (45km (28mi) of which is subsea) and was commissioned in 1986 (National Grid 2014). BritNed connects the UK with the Netherlands with a 260km (162mi) cable and National Grid is a half owner with TenneT (Dutch electricity transmission system operator) (National Grid 2014). The Moyle interconnector connects Northern Ireland with mainland UK and became operational in 2001. The East West connects the Republic of Ireland with mainland UK and became operational in 2012 (National Grid 2014).

[46] The concepts and literature around resource grabbing and green grabbing are explored in more depth in Chapter 3 Resource Peripheries.

[47] The UK-Belgium interconnector would be the first electricity interconnector between these two countries with a 150km (93mi) subsea cable and has a planned completion date of 2019, depending on planning consent and regulatory treatment. The UK-Norway (North Sea Link) proposed interconnector that would involve 700-750km (435-466mi) of subsea cable with an operation date of roughly 2020. The UK-France interconnector would be a second interconnector with France with 230km (143mi) of cable with an expected operation date of 2020. The UK-Denmark interconnector would be roughly 600km (373mi) and has been undergoing feasibility studies beginning in 2013. The UK-Iceland interconnector would be the longest interconnector in the world if built and National Grid is currently investigating the feasibility of the project with Icelandic transmission. The UK-Ireland proposed interconnector would add additional interconnectors to connect the UK.

Figure 18 Map of the current and proposed UK interconnectors by the National Grid (Source: National Grid 2014, p.1).

Interconnectors also connect the electricity system within the UK such as to some of the Scottish islands. However, not all Scottish inhabited islands' grids are connected to the Scottish mainland, for example the Shetland Islands.[48] There are proposals to connect or reinforce connections to many of the Scottish islands, such as to the Western Isles and Shetland (shown in Figure 19). The Scottish Government (2013a) notes the role of

[48] There is a proposal to build an interconnector to Shetland (see Chapter 8 Shetland Interconnector for the detailed case).

interconnectors for the Scottish islands in that, “grid access and transmission charging problems must be addressed so that Scotland’s islands can fully contribute to renewable and decarbonisation targets” (The Scottish Government 2013a, p.33). The role of these interconnectors is to facilitate the transport of renewable energy away from these Scottish islands (a part of the periphery) rather than to develop this energy for the consumption of energy on the islands, within the periphery.

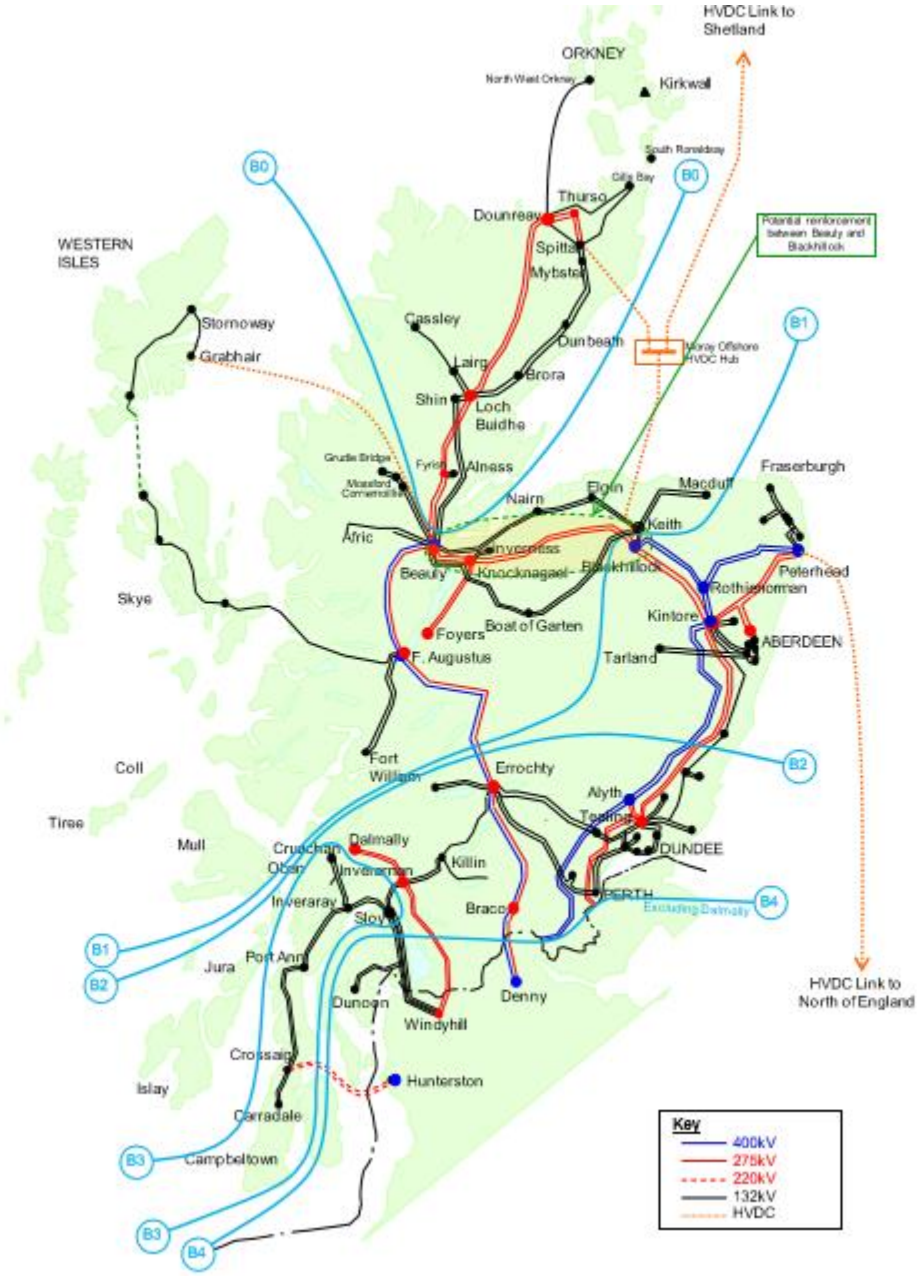

Figure 19 Map of potential Scottish transmission system reinforcements (Source: Electricity Networks Strategy Group 2012, p.18).

6.2.3. Renewable Energy Technology

There are various renewable energy technologies to capture different types of energy located mainly in peripheries but also to some extent in cores. The amount of electricity generated from renewable sources has increased in the UK with 83.3TWh produced in 2015 (total UK electricity production 337.7TWh) which is a 29% increase from 2014 (DECC 2016). The installed capacity of renewable electricity was 30GW at the end of 2015 (DECC 2016). The main renewable electricity production technology types are: hydropower, wind energy, biomass, and solar PV, with tidal and wave power in the earlier stages of development and commercialization (DECC 2013b). The amount of renewable electricity generated from each of these sources in the UK in 2015 are: hydropower 6.3TWh, wind energy 40.4TWh, bioenergy (including co-firing) 29.0TWh, and solar PV 7.6TWh (as shown in Table 11) (DECC 2016).

Table 11 Electricity generated from each source in 2015 in TWh (Data Source: DECC 2016, p.9).

Type	TWh	Percentage
Coal	76.3	22.6%
Nuclear	70.3	20.8%
Gas	99.8	29.6%
Total Renewables	83.3	24.7%
Onshore wind	23.0	6.8%
Offshore wind	17.4	5.2%
Hydro	6.3	1.9%
Solar PV	7.6	2.3%
Bioenergy (inc. co-firing)	29.0	8.6%
Total	**337.7**	**100%**

Certain renewable energies are ‘intermittent’ such as solar, wind, and water. This intermittancy is because they have daily and seasonal fluctuation in terms of their availablility and intensity. This intermittancy is problematic as Calvert and Mabee (2014) describe,

> In the context of stable and predictable energy inputs from fossil and fissile resources, power systems and energy markets have evolved to expect a continuous flow of energy at a known rate. As such, considerable social and technical manipulations must occur in order to accommodate the temporal inconsistencies associated with many RE [renewable energy] resources. (Calvert & Mabee 2014, p.19)

Investments are continuously made in research and technology in order to develop more efficient and different energy technologies. Development of marine energy technology in part takes place in Scotland at the European Marine Energy Centre (EMEC) on Orkney which is the only accredited full-scale test site for wave and tidal devices.

Hydropower was particularly expanded during the post-war years (1945-1950s) (Munro & Ross 2011). Since 1963 only one new sizeable hydropower station has been built (P. Younger 2014). There are a number of different types of hydropower including: reservoir (storage capacity), run-of-river, and pumped storage (Egré & Milewski 2002).[49] Pumped storage schemes are similar to conventional reservoir projects except they pump water into an upper reservoir when there is surplus electricity at off-peak demand times and reverse flow to generate electricity during peak demand from the electricity grid. Hydro pumped storage is, "currently the only electricity storage technology which can operate on a commercial scale" (Scottish Renewables 2015a, p.1). The UK has used pumped storage historically to bridge relatively short term demand and generation variations. As Fulton (1966) describes it,

> The impetus to use pumped storage seems to have sprung from two different influences. One, probably the first in point of time, was the need to find some way of making use of very cheaply produced electricity instead of letting it go to waste; the other was the possibility of providing by pumping, instead of by large investments in dams, the storage needed to ensure firm output from installations designed to meet the peak demands of a supply. (Fulton 1966, p.220)

At this time the expansion of nuclear generated electricity meant that there was 'excess' electricity being produced at times of low demand because nuclear power takes relatively long periods of time to increase and decrease power production compared to the variations in demand (Liébana Villela 2015). The National Grid as the system operator ensures that electricity demand is met and purchases 'balancing services' which pumped storage is particularly effective at.[50] The UK has 3GW of pumped storage capacity (Scottish Renewables 2015a). Other countries in Europe have larger pumped storage

[49] Reservoir projects involve a dam that impounds water in order to control the flow and store water. Run-of-river projects utilize water flow within a river's natural range so power output is largely affected by the variation of flow throughout the year.

[50] These services include: frequency response (second-by-second balancing of generation), fast reserve (short notice reserve (less than 20 seconds) for short periods of demand), reactive power (provides a stable voltage), and black start (when the network needs to be re-energized this provides the 'kick start' for thermal and nuclear plants) (Parliamentary Office of Science and Technology 2008). The demand for these 'balancing services' "is predicted to grow significantly in future years with the increase in new inflexible and variable generation being developed" (Scottish Renewables 2015a, p.3).

capacity such as: Germany (6GW), France (4.5GW), and Austria (8GW) (Scottish Renewables 2015a).

Wind turbines are a technology that have a long history relative to other current renewable energy technologies and can be located onshore or offshore. The majority of wind turbines in the UK are located onshore with an installed capacity of 3.5GW for offshore wind compared to 7.0GW of onshore wind as of 2013 in the UK (DECC 2013c). It is more expensive to install and operate wind turbines offshore but there are advantages such as more frequent and powerful winds (Mackenzie 2006b). The UK has favourable features for offshore wind development because a significant portion if its coast has shallow water depth with consistent high wind speeds (Hodson et al. 2015). Scotland's offshore wind resource is less accessible than in England because of the relatively deeper waters along Scotland's coast which make constructing and maintaining them more expensive (Toke et al. 2013).[51] However, the combination of Scotland's hills and wind speeds make for large energy generation potential (Toke et al. 2013).

Biomass energy is produced from plant or animal matter and can be used to produce electricity, heat, or in the transport sector (DECC 2013c). The two main fuel types are purpose-grown energy crops and unwanted human activity products, or wastes (Boyle 2004). Wastes can also be used such as wood residues from forestry or animal wastes such as sewage sludge and animal manure. However there is a limit to the amount of biomass available to be converted into energy because there are other demands on agricultural land such as for food crops and a limited amount of waste is produced that is currently viable for bioenergy.

Solar PV is a versatile and scalable technology. However the UK is not ideal in terms of solar radiation which varies by latitude and region. In 2013 there were a total of

[51] There are new developments offshore wind including plans for the first floating wind farm to be built roughly 25-30km (16-19mi) from the Peterhead coast in Scotland, called the Hywind Scotland Pilot Park (30MW). Hywind is owned by Statoil (Norwegian multinational oil and gas company) and will be 30MWs consisting of 6MW turbines floating in waters over 100m deep. The onshore construction is to occur between 2016 and 2017 with final commissioning taking place in 2017. The advantages of a floating wind farm include the ability to tow the turbines to locations where it is easier to perform maintenance on them as well as the ability to move and angle them depending on weather in order to optimize the capture of wind.

2.4GWs of installed capacity of solar PV, of which 1.7GWs was mainly domestic, small-scale generation (DECC 2013c). Research continues into ways to make solar PVs more efficient at converting solar energy into electricity with current conversion efficiencies of commercially available PVs at roughly14-22% (Schultz *et al.* 2007). However, further development has achieved conversion efficiencies of up to 44.7% (Soitec 2014). The cost of solar PV has drastically decreased over the past decade which has aided in its wider deployment.

Tidal energy technology is further advanced than wave technology as it has moved past the demonstration phase into commercialisation (DECC 2013c). Tidal power has the advantage that it is predictable in its intermittency. There are a range of types of tidal energy devices including: tidal barrages, tidal lagoons, and tidal streams.[52] The world's first grid connected commercial-scale tidal device was the SeaGen 1.2MW device in Northern Ireland, in 2008 (Devine-Wright 2011b). Recent tidal projects in Scotland include the Shetland Tidal Array that involves deploying three 100kW tidal devices.[53] There are also plans for larger tidal stream schemes such as the MeyGen project in the Inner Sound of the Pentland Firth located between Orkney and the mainland of Scotland (6MW Phase 1A).

Wave energy is in the early stages of development and is at the demonstration phase (DECC 2013c). Wave energy increases in the winter when the demand for electricity is also higher. A large range of wave energy capturing devices have been proposed and studied, and are at various stages of development. These various devices are in a sense 'competing against each other' as they are being developed and it is not yet clear which will 'win' (Falcão 2010). Some wave devices have made it to the prototype deployment stage in Scotland, such as the 75kW wave energy prototype installed on Islay

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[52] Tidal barrages involve turbines being mounted in a barrage across an estuary and the vertical rise and fall of tides is captured. A tidal lagoon is where a tidal pool is enclosed on a high level tidal estuary so that water can be trapped during high tide in the barrage and then released through turbines as the water level changes with the tide. Tidal streams capture the horizontal energy flow of tides using submerged turbines where there are fast, free-flowing tidal currents.

[53] The developers include Nova Innovation (Edinburgh based company) in collaboration with Elsa (Belgian based company). One turbine has been deployed and the additional two tidal devices are expected to be added to the array by 2018.

in 1989 (Boyle 2004). The Scottish Government changed the way in which they funded wave technology development in 2014 in part because wave technology development was lagging behind expectations, particularly compared to tidal technology. The funding system in part was blamed for the status of wave technology innovation with a need for more cooperation than competition. The funding change involved the creation of Wave Energy Scotland (WES) in 2014 to support the wave energy industry through funding packages. This meant that the previous public funding system for wave energy development companies was withdrawn in December 2014 and some companies (who rely on private and public funding) such as Aquamarine Power and Pelamis Wave Power went into administration and ceased operating.

6.2.4. Policy

Governmental commitments to national and international targets are one of the dominant processes influencing and driving the energy regime. Scotland's energy is governed by a multi-level governance structure: European Union (EU) [54], UK, and Scotland. International agreements also play an important role in shaping policy as they are the global context that represents world ambitions within which the UK and Scotland set their targets. International agreements relating to renewable energy include the Kyoto Protocol and the Copenhagen Accord.[55] Policy instruments are key factors in renewable-sourced electricity expansion in part because of the current higher cost of most renewables over more conventional sources such as coal or gas (Geels 2015). These instruments include energy policy plans, financial incentives (feed-in tariffs), and regulations (renewable obligations) (Geels 2015).

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[54] The UK held an EU membership referendum on whether to remain a member of the EU in June 2016. The results of the referendum were that 51.9% voted to leave the EU. However, Scotland voted in favour of remaining in the EU by 62%. The UK has been a member of the European Economic Community since 1973, which later became part of the EU when it formed in 1993.

[55] The Kyoto Protocol came into force in 2005 with the aim of combating global warming as a protocol to the United Nations Framework Convention on Climate Change. The Copenhagen Accord was agreed upon at the United Nations Climate Change Conference in 2009 by 49 country representatives.

European Renewable Energy Policy

The EU holds powers to set binding targets for members. Countries within the EU can set their own more ambitious legally binding targets for GHG emission reductions as long as they meet their commitments with the EU. The EU has a set of GHG emission and renewable energy related directives, frameworks, and roadmaps with time scales for targets ranging from 2020, 2030, and 2050. The EU adopted the EU Climate and Energy Package in 2008 that committed them to legally binding targets of a 20% reduction in GHG emissions, a 20% improvement in energy efficiency, and 20% EU energy consumption sourced from renewables, all by 2020 (European Union 2014). To achieve these targets, states can import renewable electricity from other member states (Toke et al. 2013). The EU also has a 2030 Framework that includes 2030 targets of: 40% reduction in GHG emissions compared to 1990 levels, minimum 27% share of renewable energy consumption, and minimum 27% energy savings (relative to the business-as-usual scenario). The EU's long-term goal for reducing GHG emissions is 80% to 95% by 2050 relative to 1990 levels (European Commission 2011). For the 2050 target the European Commission has an Energy Roadmap (2011) outlining energy development around: energy efficiency, renewable energy, nuclear energy, and carbon capture and storage, in a 'technology-neutral framework'. The European Commission hopes these targets will send, "a strong signal to the market, encouraging private investment in new pipelines, electricity networks, and low-carbon technology" (European Commission 2015a). This European-scale approach to the 'energy challenge' is argued by the European Commission (2011) to, "increase security and solidarity and lower costs compared to parallel national schemes by providing a wider and flexible market for new products and services" (p.3).

Additional to the targets and directives, the EU has an Energy Union strategy as of 2015. This Energy Union has a specific vision for the electricity sector that involves energy source diversification, emission reductions, and a fully-integrated internal energy market. This vision for an internal energy market has significant core-periphery implications as it is meant to create a more competitive electricity market that connects cores and peripheries. This increased competition is described by the European Commission (2015b) as,

> An interconnected European energy grid is vital for Europe's energy security, for more competition on the internal market resulting in more competitive prices as well as for better achieving the decarbonisation and climate policy targets which the European Union has committed to an interconnected grid will help deliver the ultimate goal of the Energy Union, i.e. to ensure affordable, secure and sustainable energy, and also growth and jobs across the EU. (European Commission 2015b, p.2)

The main benefits of the Energy Union strategy outlined by the European Commission for an interconnected energy system are: increasing security of supply, affordable prices in the internal market, and decarbonising the energy mix (European Commission 2015b). Interconnectors support this 'decarbonising the energy mix' because, they reduce, "the need for investment in peak generation capacity and storage because the plants that each country has would not be needed at the same time" (European Commission 2015b, p.3). The European Commission has targets for electrical interconnection between EU member states,

> Member States have increased their interconnection capacities during the last decades. However, twelve Member States, mainly in the periphery of the EU, remain below the 10% electricity interconnection target and are thus isolated from the internal electricity market. (European Commission 2015b, p.4)

This quote illustrates how parts of the EU are considered in the 'periphery' with limited interconnection of their electricity grid with the EU, making them 'isolated' within what is considered an 'internal' electricity market at the EU level, representing one scale of core-periphery dynamics. However, there are negative implications to interconnectors as they connect peripheries and cores leading to potentially further peripheralization and resource grabs as discussed in more detail in later chapters (Chapter 10 Analysis and Chapter 11 Discussion).

One of the main advocacy groups in support of an interconnected Europe is the Friends of the Supergrid (FOSG) based in Brussels. They are a group made up of companies that are lobbying for the creation of a 'supergrid' which they argue they would be able to deliver in terms of the infrastructure and technology. The FOSG's approach is through, "promoting and influencing the policy and regulatory framework required to enable a European Supergrid" (Friends of the Supergrid 2014).

UK Renewable Energy Policy

The UK Parliament reserves the power (in relation to Scotland) to make laws about energy. The UK Government has a Department of Energy and Climate Change (DECC). The UK has set targets through the UK Climate Change Act (2008) with a mandatory target of GHG emission reduction levels of 34% by 2020 and 80% by 2050 (based on 1990 levels) (DECC 2009c). This Act was a 'major shift' in terms of policy and approach for the UK (Carter & Jacobs 2014). It positioned the UK as the first country to have a legally binding framework to cut carbon emissions (Hodson et al. 2015). The dominant approach taken by the UK has been to promote, "a range of market-based technology-led responses including: the marketized construction of new offshore wind production systems; the promotion of low carbon vehicles and associated infrastructures; a market-based mechanism, the Green Deal, for retrofitting the UK's housing stock; and the reconfiguration of the electricity grid to facilitate and be compliant with these and other new forms of electricity generation and consumption" (Hodson et al. 2015, p.5). The Green Deal to upgrade the UK housing stock was launched in 2013 and has been considered a 'failure' in part due to the low uptake and the scheme was closed in 2015 (Marchand et al. 2015; Badi et al. 2017).[56] It is important to acknowledge that there are constraints to achieving such government set targets which can include social acceptance in the market or community (Wüstenhagen et al. 2007).

The main UK-wide policy instrument used to increase renewable electricity production through financial incentives is the Feed-In-Tariff scheme (FITs) which came into effect in 2010 (Bergmann & Hanley 2012).[57] The scheme is administered by Ofgem

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[56] Badi et al. (2017) found that the 'failure' of the Green Deal was related to poor policy design, lack of mechanisms to engage with consumers, and trust between actors.

[57] The FIT scheme came into law through the Energy Act (2008). Generators that qualify receive a generation tariff at a set rate (guaranteed level for the period of the tariff which is up to 20 years) for each unit of electricity generated. If energy is fed into the main grid then there is an additional export tariff. However, the tariff level will decrease over time for new generators which will vary depending on the technology.

but the policy decisions about the scheme are made by Department of Energy and Climate Change (DECC). The FIT scheme applies to small-scale renewable energy projects (less than 5MW production). The scheme guarantees a price set over the market price (depending on the technology and scale) which incentivises renewable energy projects (Bergmann & Hanley 2012). The FIT scheme incentivizes renewable energy development in peripheries that can easily connect to the National Grid because of the additional export tariff to feed into the National Grid. There are also implications for peripheries as the tariff levels decrease over time for new generators where parts of the periphery that do not develop their renewable energy quickly could miss the highest incentives unless costs for development also decrease to compensate.

The Renewables Obligation (RO) and Renewables Obligation (Scotland) (ROS) (discussed in the next section 6.2.4.3 Scotland Renewable Energy Policy) will be replaced by the UK-wide Contracts for Difference (CfD) scheme which opened applications in 2014 (administered by the National Grid).[58] Scotland has a statutory consultation role for the CfD's design and delivery. The CfD is held by low carbon electricity generators (including nuclear) that are awarded contracts that guarantee them a 'strike price' (price different between the price of producing the electricity and the average market price). The first round of CfDs awarded contracts to 27 projects. The CfD creates a more competitive form of providing incentives to renewable energy producers.

In 2014 DECC launched a national Community Energy Strategy (2014b). At the time of the report there were found to be at least 5,000 active community energy groups 'geographically dispersed' throughout the UK since 2008 (DECC 2014a). This strategy outlines that communities can become more involved in energy through participating in: generation, reducing use, managing energy, and purchasing energy (DECC 2014b, p.4). Smith et al. (2015) notes that this Community Energy Strategy is important in that it, "signifies remarkable recognition of grassroots initiative in sustainable energy" (p.2). Although this strategy is a UK level policy, Strachan (2015) notes that, "interest in

[58] There is an overlap between the ROs and the CfD called the 'transition period' between 2014 (beginning of CfDs) and 2017 (end of ROs). During this overlap period electricity generators that qualify can choose between the schemes, CfD or RO.

community renewables has arguably been more prominent among the devolved governments, especially Scotland" within the UK (Strachan et al. 2015, p.100). This contrast is perhaps because of the difference in governments in Scotland with the SNP government compared to the UK with a conservative government. The Strategy does not include targets for community energy development however Scotland has its own set targets for community energy (outlined in the next section of this chapter 6.2.4.3 Scotland Renewable Energy Policy). The response by the renewable energy community to DECC's Strategy has been, "a mixture of gratitude for policy recognition but disappointment in the extent of its support" (Smith et al. 2015, p.16).

Scotland Renewable Energy Policy

Scotland is able to influence the energy sector through policies that can set targets even though the UK has reserved energy policy powers. Scotland has passed its own climate change act, the Climate Change (Scotland) Act 2009, legally committing them to goals that reduce GHG emissions by 42% by 2020 and 80% by 2050. The Scottish Government can also approve and refuse planning applications for new energy developments. Scotland has the 2020 Routemap for Renewable Energy Scotland (2013a) which sets a target for 2020 of equivalent of 100% of electricity demand in Scotland to be from renewable sources.[59] The interim target of electricity demand from renewables is 31% by 2011 which was met and a new interim target of 50% was set for 2015 (The Scottish Government 2013a). The 2020 Routemap (2013a) describes the Scottish Government's role in decarbonizing the electricity sector,

> Making renewables the cornerstone of our future energy supply means that we will need the right infrastructure, processes and support to be in place and fit for purpose. In a regulated energy market, the Scottish Government exerts its influence through its targets, its powers in areas such as planning, consents and the Renewables Obligation (Scotland), and by providing targeted support and incentives. (The Scottish Government 2013a, p.13)

The main policy instrument in Scotland to incentivise renewable energy production expansion is through the Renewables Obligation (Scotland) (ROS) that was

[59] The 2020 Routemap for Renewable Energy Scotland (2013a) is an updated extension from the Scotland Renewables Action Plan (2009).

introduced in 2002 (Bergmann et al. 2008). The RO and ROS is being replaced by the UK-wide Contracts for Difference (CfD) scheme (described in the previous section 6.2.4.2 UK Renewable Energy Policy). The ROS works in tandem with the Renewables Obligation (RO) that covers England and Wales (Government of the United Kingdom 2014).[60] The RO and ROS are market-based mechanisms to incentivise renewable energy electricity generation, for schemes that are larger than 5MW, so that they can compete with traditional, cheaper alternatives. The RO and ROS are tradable certificate schemes that also require licensed UK electricity suppliers to have a specific proportion of their electricity sourced from eligible renewable sources.[61] The specific proportion is increased annually. Generators of eligible renewably sourced electricity can sell their Renewables Obligation Certificates (ROCs) to suppliers or traders in order to meet their RO or ROS obligations with regard to their proportion of renewably sourced energy. Ofgem administers the ROS (on behalf of Scottish Ministers) as well as for the RO in the rest of the UK. New generators of renewables can only apply to participate in the scheme until 31 March 2017, after which all accredited RO electricity generators will still receive their full lifetime support of 20 years which then marks the end of the scheme (2037) (Government of the United Kingdom 2014). However, changes have been made with the early closure of the RO and ROS for large-scale solar PV (closed April 2015) and new onshore wind power projects (closed April 2016 which is one year earlier than originally planned). These closures were not made by the Scottish Government because the Secretary of State (UK Government level) received powers over the closure of the ROS, which Scotland previously held itself, through the Energy Bill in 2013 (Lords Amendment 54) (House of Lords 2013). Scottish Renewables has argued that these early closures to subsidies have reduced investor confidence and could result in Scotland not

[60] Prior to the RO there was the Non-Fossil Fuels Obligation (NFFO) created in 1990 as a way to protect nuclear power after the privatization of the electricity industry in the UK (1990) (Geels et al. 2015). The NFFO required a certain amount of nuclear power to be purchased by electricity companies which was compensated for by a subsidy from the Fossil Fuels Levy (Geels et al. 2015). Renewable energy technologies were later included in the NFFO.

[61] The initial new renewable generation portion was set at 3% for 2002-3, rising annually to 15.4% in 2015-16 (Government of the United Kingdom 2014).

reaching its target of 100% of electricity demand or equivalent from renewable sources by 2020 (Scottish Renewables 2015b).

In Scotland there is legislation around community-land ownership and targets for community renewable energy development. Crofters were enabled to purchase their lands under the 1976 Crofting Reform (Scotland) Act.[62] This community land ownership has enabled many communities to develop community-owned renewable energy. To support Scottish renewable and local energy development, the Community and Renewable Energy Scotland (CARES) program was created in 2011. Local Energy Scotland (LES) (founded in 2013) administers and manages CARES.[63] CARES is a loan fund for locally-owned renewable energy projects and is meant to help finance the high risk, pre-planning consent stages of these projects (The Scottish Government 2013b). These loans are only for renewable energy projects of up to 5MW in size and up to £150,000 that can cover up to 90% of the agreed costs. The Scottish Government has a target for community-owned or locally-owned renewable energy capacity (electricity or thermal) in Scotland of 500MW by 2020 (The Scottish Government 2013a). This target was met in 2015 with 508MW of operational capacity made-up of 11,940 individual installations (Energy Saving Trust 2015).

6.3. Niche

Niches are where radical innovations occur. Some niches will fail or 'drop off' while others will 'break through' to the regime level as shown in Geels' (2002) diagram of the dynamic MLP (Figure 4 in Chapter 2 Sociotechnical Transitions). Renewable energy radical innovations face considerable barriers as they need to both, "overcome prevailing standards and to compete against the network externalities of established products or technologies" (Markard & Truffer 2006, p.609). However, it is possible for radical innovations to breakthrough for example with technological advances or changes in the political agenda (Markard & Truffer 2006). There are a range of niches that exist in

[62] This was later followed by the Land Reform (Scotland) Act (2003) put in place by the Scottish Parliament.

[63] LES is a consortium including the Energy Saving Trust, Changeworks, The Energy Agency, SCARF, and The Wise Group.

the UK with respect to renewable energy and electricity. The main renewable electricity production technologies described earlier in this chapter (6.2.3 Renewable Energy Technology) are: hydropower, wind energy, biomass, and solar PV, with tidal and wave power in the earlier stages of development (DECC 2013b). These technology categories exist in a range of settings and ownership arrangements. Table 12 shows these renewable energy technologies and the different ownership types and settings representing various types of niches that exist in the UK. The first case study site of this study represents a niche for community-owned, rural tidal energy and privately-owned rural pumped hydro. In this section a few examples of other niches (circled) in Table 12 are described to illustrate the range of renewable energy niches in the UK:

- Callander Community Hydro Project (community-owned, rural hydropower project),
- Barvas Moor Wind Farm proposal (privately-owned, rural wind project),
- Galson Estate Wind Farm (community-owned, rural wind project),
- Tidal Meygen Project (privately-owned, rural tidal project), and
- LIMPET (Land Installed Marine Power Energy Transmitter) Wave Energy on Islay (privately-owned, rural wave project).

Table 12 Showing the different types of renewable energy niches present in Scotland with an X.

		Renewable Energy Technologies (Electricity)					
		Hydropower	***Wind***	***Biomass***	***Solar PV***	***Tidal***	***Wave***
Ownership	***Private***	X	(X)	X	X	(X)	(X)
	Community	(X)	(X)		X	X	
	Public						
	Community-Private Hybrid		X		X		
Grid Location	***Rural***	(X)	(X)	X	X	(X)	(X)
	Urban				X	X	

The Callander Community Hydro Project is a small-scale, community-owned, rural hydro project. The Callander Project is a run-of-river scheme located within the Loch Lomond and Trossachs National Park on Forestry Commission land. The 425kW scheme can power the equivalent of approximately 300 homes (Local Energy Scotland 2015). It is owned by the community group, Callander Community Development Trust[64] and became operational in September 2014. The scheme cost £1.9 million with funding from CARES, a consortium of banks, and selling electricity to the National Grid with FITs payments. The scheme is one of Scotland's first community-owned hydro projects and the first that is owned by a community on Forestry Commission land (Local Energy Scotland 2015). Therefore the Callander hydro scheme can be understood as a niche due to its ownership type (community) and because of its location as it is a part of the periphery.

The Barvas Moor wind farm is an example of a failed niche that was a large-scale, rural, wind farm proposal. It was a 702MW wind farm proposal on the Isle of Lewis (Outer Hebrides) for an industrial site and piece of adjacent private land (Kerr 2006; Jenkins et al. 2016). The electricity it produced would have been transferred to the UK mainland National Grid via the installation of a subsea interconnector between the Western Isles and the Scotland mainland. The first proposal in 2004 by Lewis Windpower (set up by the Stornoway Trust) was for 234 wind turbines; however 80% of local residents opposed this proposal. In 2006 a revised application of 181 turbines was put forward which polarized the community. In 2008 Scottish Ministers rejected the proposal because of the impact on rare and endangered birds (Munro & Ross 2011). It was the 'largest single proposal' for a wind farm in Europe at the time (Kerr 2006). Some literature has examined the Barvas Moor case to better understand the use of community and developer arguments for and against such development (Murphy 2013b; Munro & Ross 2011).[65] Scott and O'Neill (2013) suggest that, "although sustainable energy goals are publicly acceptable at a national level, at the point of implementation (the local scale), the deployment of wind energy often becomes more contested" (p.421). The Barvas Moor wind farm illustrates how not all niches are successful in developing past the proposal stage.

[64] The Callander Community Development Trust is a charitable organisation established in 2003.

[65] Murphy (2013b) found that greater sensitivity is needed with respect to local history, culture, and language, because of the important roles they can play in these types of settings.

The Galson Estate wind farm is a small-scale, community-owned, rural niche of three wind turbines. It initially started with the community of the Galson Estate on north Lewis organising a community land buy-out in 2004 which occurred at the same time as when the Barvas Moor wind farm was initially being proposed (Haf & Parkhill 2017). There was considerable local opposition to the proposed Barvas Moor project and the planning application was eventually rejected (Rennie & Billing 2015). The community land buy-out included the Galson Estate (56,000 acres) by the Galson Estate Trust (*Urras Oighreachd Ghabhsainn*). Since then a subsidiary trading company (Galson Energy Ltd) owned by the Galson Trust has gained planning permission for three wind turbines in 2009 and commissioned one of them in 2014 (Rennie & Billing 2015; Galson Estate Trust 2014). Funding was sourced through a number of sources (The Co-operative Bank, BIG Lottery Fund, and CARES) (Galson Estate Trust 2014). Rennie and Billing (2015) note the large contrast in opposition for the wind turbines project by the Galson Trust compared to the larger proposed wind farm of Barvas Moor in 2004 even though they were located in the same geographical area. This exemplifies the role of scale and ownership in resource developments, in this case in the periphery of the Outer Hebrides.

The Meygen[66] Pentland Firth tidal project is an example of a privately-owned, rural niche for tidal power. The project is located in the Inner Sound of the Pentland Firth between Orkney and the mainland of Scotland. The project received planning consent in September 2013 for 86MW and financial closure in 2014 (The Scottish Government 2013a). However, the initial Phase 1A of the MeyGen project has a capacity of 6MW (four 1.5MW turbines by Atlantis and Andritz Hydro Hammerfest) operational in the summer of 2016 (Meygen 2016). This initial phase of 1A plans to be run for 25 years and MeyGen has plans to 'build-out' with additional phases to the full lease capacity of the site of 398MW. It will be 'the world's first multi-turbine tidal stream energy project' (Meygen 2016). The Meygen project is a niche for tidal power representing the early stages of large-scale tidal deployment, and is located on Scotland's northern coast, which can also be understood as part of the periphery.

[66] Meygen was established in 2010 and is 86% owned by Atlantis.

The LIMPET (Land Installed Marine Power Energy Transmitter) wave energy device on the isle of Islay is a privately-owned, rural niche for wave energy. Prior to the LIMPET device there was an initial wave energy prototype of 75kW in 1989. This was followed by the LIMPET (installed capacity 500kW) in 2000 (Queen's Unviersity Belfast 2002). The LIMPET was the, "world's first commercial-scale wave power station" connected to the electricity grid (DECC 2009b, p.186). The projects were developed by Wavegen and Queen's University Belfast with support from the EU. The LIMPET device is located on the shoreline with no moving parts within the water. Wavegen (founded in 1990) was sold in 2005 to Voith Hydro.[67] The LIMPET along with Wavegen ceased operating in 2013 (Boyle 2004). Wave energy has not yet broken through to the commercial-scale of development despite this niche of the LIMPET having been development in 2000. As discussed earlier in this chapter (in 6.2.3 Renewable Energy Technology), wave energy technology has not been fully commercialised. This wave energy project is an example of a niche that was successfully built but has thus far 'dropped off' as it has been shut down and there have been no further commercial-scale wave power stations in the UK thus far.

6.4. Conclusion

This chapter has outlined the existing electricity system in Scotland. The three levels of the electricity sociotechnical system (landscape, regime, and niche) were used to organize and discuss the system. Key core-periphery issues were also highlighted throughout this chapter including: geography, scale, ownership, and import-export. Renewable energy production has become widely recognized to be of particular strategic significance for rural areas in Scotland, in order to improve the area's economic and social well-being (Mackenzie 2006b). A large number of renewable energy sources have already been developed in Scotland and the rest of the UK as shown in Figure 20 and Table 13.

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[67] Voith Hydro is a German joint company between Voith and Siemens.

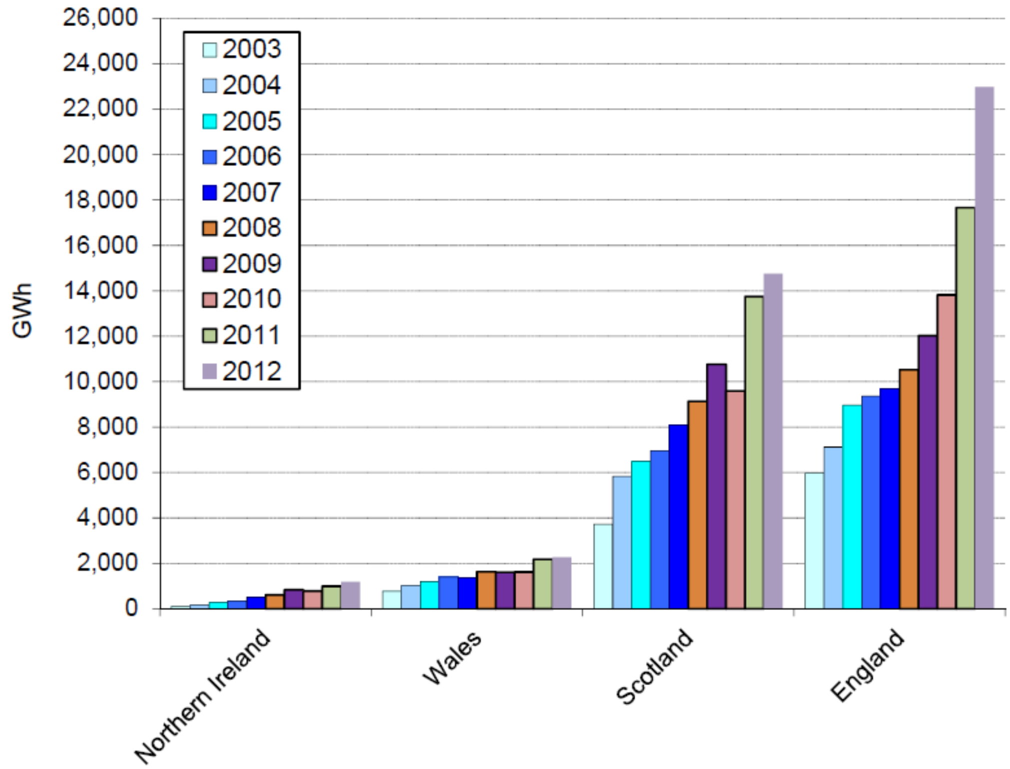

Figure 20 Renewable energy generation trends by country (Source: DECC 2013a, p.56).

The UK had 30GW of installed renewable electricity capacity at the end of 2015 which was a 22% increase from 2014 (DECC 2016). The percentage of electricity generated in the UK from renewable sources was 24.7% in 2015 compared to 19.1% in 2014 (DECC 2016). This renewable energy development and potential for further development in peripheral regions has connected these areas to landscape pressures and regimes such as the energy agendas of Scotland and the UK as well as international protocols and conventions (Mackenzie 2006b).

Renewable energy generation trends by country (Source: DECC 2013a, p.56).

Table 13 Number of and installed capacity (MW) of renewable energy sources generating electricity as of 2012 (Data Source: DECC 2013a).

		England	**Wales**	**Scotland**	**Northern Ireland**
Number of sites	Hydro	206	103	305	55
	Wind and wave	2,816	341	2,265	123
	Landfill gas	358	23	45	6
	Sewage gas	162	16	8	3
	Other bioenergy	210	10	25	16
	Solar PV	311,192	27,173	24,360	531
	Total	314,944	27,666	27,008	734
Installed capacity (MW)	Hydro	32.1	149.9	1,495.80	8.4
	Wind and wave	3,899.5	605.6	3,933.50	456.7
	Landfill gas	864.9	45.20	115.2	10.7
	Sewage gas	177.2	13.1	8.2	0.2
	Other bioenergy	1,825.2	18.5	161.1	11.3
	Solar PV	1,369.6	97.2	87.2	5.5
	Total	8,168.5	929.5	5,801	492.8

The implications of renewable energy development are complex and far reaching. The rapid expansion of projects driven by targets set at the national level and schemes designed to support meeting these targets is creating opportunities in communities, particularly in the peripheries of Scotland. These opportunities also have major implications for resource peripheries that are complex.

Chapter 7.

North Yell Tidal Scheme

The first of three cases that make up the collective case study of this research is the community-owned North Yell Tidal Scheme located on one of the north isles of Shetland, Scotland. This scheme was briefly described earlier in Chapter 5 Methods. Nine interviews were conducted in direct relation to this case. The empirical evidence for the North Yell Tidal Scheme is presented in this chapter along with contextual information about the region and relevant system. This chapter is structured by beginning with information about the focus of this case, the North Yell Tidal Project and then expanding outwards to the Isle of North Yell and then to Shetland. This structure was chosen because it mirrors the nested nature of core-peripheries as shown in the theoretical diagram developed by this study in Chapter 4 Towards an Analytical Framework (Figure 12). North Yell can be understood as a periphery to the Shetland mainland. This core-periphery relationship can be understood to be nested within the core-periphery relationship between the Shetland Isles and the Scottish mainland.

This chapter begins with an outline of the North Yell Tidal Project. To put this case in context, background information for the Isle of North Yell as a periphery to the Shetland mainland is then presented. Next the dynamics and influences of renewable energy development on Shetland as a periphery to the UK are described. This includes the broader role renewable energy plays in various Shetland policy documents because these policies, as part of the regime level of the sociotechnical system, have been one of the important shaping factors of this resource development and transition.

7.1. North Yell Tidal Project

The North Yell Tidal project is the first community-owned tidal scheme in the world. The project is a collaboration between the North Yell Development Council (NYDC) who own the device and Nova Innovation, an Edinburgh-based technology company. The seabed lease is held jointly between NYDC and Nova. The tidal device was installed in April 2014 after nearly five years of planning and preparation. The tidal device is a 30kW Nova 30 turbine prototype. It is located 1km (0.6mi) from the shores of Cullivoe on North Yell, Shetland, in the Bluemull Sound and is connected by a subsea cable to the local grid where in the vicinity there are thirty homes, Cullivoe Harbour Industrial Estate, and a locally-owned ice plant. The purpose of the North Yell Tidal project, as described by a member of a Scottish Government agency on Shetland, is "for testing in the waters there at Cullivoe and with a view to future revenue generation and possible development of further tidal array sites and development of tidal energy in Shetland generally" (06). This quote illustrates how the North Yell project is seen as a niche with potential to lead to further tidal development in the near vicinity (Bluemull Sound) and region (Shetland).

The project is a partnership between NYDC and the Leith-based energy company Nova Innovation. Nova Innovation was founded in 2010. They put an emphasis on securing local supply chains, as demonstrated by their supply chain being 80% Scottish-based (Nova Innovation 2014). Nova's vision for marine energy development is 'pan-European' in scope with the North Yell scheme as part of this, as described by Simon Forrest, Managing director of Nova Innovation,

> This partnership agreement will accelerate Nova Innovation's technology development; help secure the company's Scottish manufacturing base and expand the integrated supply chain here in Shetland and Scotland. The pan-European vision of the partnership will open up export markets and deliver real growth for the marine energy sector. (Shetland Times 2014)

The NYDC and Nova have been working together since roughly 2010 to develop the project. The NYDC is a community development organization and registered Scottish Charity. The NYDC holds a trading subsidiary for the tidal project, Bluemull Tidal Energy Limited. There are a range of funders for the North Yell project. These include funding from the Scottish Government's Community and Renewable Energy Scheme (CARES)[68] (£167,763), Shetland Islands Council (£16,990), and NYDC (£1,200) (The

[68] CARES (as discussed in Chapter 6 Existing Energy System) is a loan fund that became operational in 2011 for locally-owned renewable energy projects and is meant to help finance the high risk, pre-planning consent stages of these projects (The Scottish Government 2013b). The purpose of the program is to aid community

Scottish Government 2014e). Highlands and Islands Enterprise (HIE) is also involved in the North Yell Tidal Project because they gave funding to recruit a project manager to work on a number projects including the tidal project with the aim of community regeneration and economic development (Highlands and Islands Enterprise 2013).The NYDC has been described by an interviewee who is a resident of North Yell as a well-established organization which aided in its attracting funding for the project.

> We are a very established community on Yell even though it is a very small community group, NYDC have been around for some 70 years. We have a pretty good track record of achieving what we have set out to do. All the facilities down at the harbour have come about directly because of us, the NYDC have campaigned for them and developed them. (01)

Fieldwork indicated there is large community support for the North Yell Tidal Project albeit for different reasons. One interviewee local to the area described this support as, "everyone was very enthusiastic particularly because it was a new technology" (01). One of the community's motivations for the project is centred on vulnerability and desire for independence as described by an interviewee involved in a community development organization on North Yell,

> We always feel very vulnerable. So as much as we can do for ourselves the better… We are always influenced by factors we have no control over. So the more independent or self-sufficient we can become the better and if there is good employment elsewhere that is great but if it falls away again then at least there is something to fall back on. (01)

There has also been involvement in the tidal project by local businesses. For example the tidal device was deployed by a local towboat company, and a local company, Shetland Composites, built the blades for the device. For Shetland Composites this has led to expansion and a subsequent contract to manufacture blades for an array of tidal devices deployed in the Bluemull Sound during the summer of 2015 (Shetland Tidal Array) (The Scottish Government 2014c).

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groups and smaller businesses with the early stage loan financing for renewable energy projects which is widely viewed as a barrier to these types of projects.

There were administrative delays as the planning phase for the tidal device took a longer period of time than had been originally anticipated. This was described by an interviewee from a member of a Scottish Government agency as, “they were very optimistic about dates originally; they thought the turbine would be deployed within a year at that point and it was a lot later in the end” (07). The reasons behind these delays were in part attributed by the same interviewee to the time it took for the project to be processed for planning approval, it was “slow getting through the system” because the, “paperwork is built for big devices and big schemes, they have to fill in a huge paper load… just for 30KW” (07). Acquiring grid connection permission was also identified as a challenge and time consuming. One interviewee a part of a community organization in Shetland (01) described how the processes to acquire the permissions for connection to the National Grid occurred relatively quickly because of the Shetland Northern Isles New Energy Solutions (NINES) (described later in this chapter), a project led by Scottish Hydro Electric Power Distribution. Fieldwork indicated that this frustration over the length of time the project took to deploy was felt by both parties, Nova and the NYDC, as well as the broader local community of North Yell. Nova was also under financial pressure during this process because of the costs involved before the device was deployed and could begin generating income by selling electricity to the National Grid.

The working relationship between NYDC and Nova has been strained at times as their differing expectations and needs caused friction. This friction revolved around: miscommunication, ownership, liability, and information sharing. At one point the tidal turbine was turned off in 2014 as part of a dispute that largely involved a miscommunication however the device was turned back on and a mediator was hired by Highlands and Islands Enterprise (HIE) (at the end of 2014) to aid in resolving the conflict. It was claimed in one interview with a member of a Scottish Government agency indirectly involved in the project (07) that these issues largely stemmed from the original contract between Nova and NYDC not being explicit regarding liability, timing, and splitting of income and costs. There was a period of time where these frustrations meant that some of the local North Yell community wanted to ‘walk away’ from the project, however there were obligations in terms of funding as described by the same member of a Scottish Government agency,

> There were grumbling noises from Nova and the community about getting very fed up with it, and some of them [the community] are saying just pull it up and take it away, we don't care. Because the NYDC are exposed now because they have a grant that says that they will run a device and actually if the device is picked up and taken away they still have to pay this grant back, they aren't allowed to keep the grant, so now they are exposed to £250,000 debt, and their [the NYDC] income is about £300,000 a year, so that would destroy them. (07)

The mediation between NYDC and Nova made progress to resolve some of the issues. Nova has taken full liability for the device and agreed to be, "more forthcoming about what its power output is and things like that which they were trying to be very secretive about" (07). The sharing of information regarding the project and the performance of the tidal turbine has been a point of contention. Nova was described by the same interviewee as being, "very possessive about press releases going out about the device and sometimes it got a bit difficult and a bit tense" (07). Since the tidal device is a prototype Nova has a need to be closed to some extent about the information they share about their device since it is a new technology which involves proprietary information. The lack of information sharing also included the timing of the installation of the tidal device as described by a member of a Scottish Government agency indirectly involved in the project,

> Spring 2014 the device is put into the water very hush hush, very secret. HIE see us as completely side-stepped, we found out from an article in the paper, after the event. Because we thought well we want to make a big deal out of this locally... it's a big first time in Scotland maybe even in Europe that anybody's done this. (07)

This quote illustrates how there was a sense by certain actors indirectly involved in the project, such as HIE, that they were left out and unable to publicize the success of the project in the way that they would have liked due to lack of communication and information sharing.

There is a certain amount of risk involved with new and developing technologies. One interviewee involved in a community development organization on Shetland described how the fact that tidal technology is to some extent still an unproven technology was perceived as an incentive for their community project,

> But when it is really new and unproven, then we felt as a group that it could benefit everybody if we gave the industry a step up and try and encourage local businesses to be involved, and that would take some of the risk away from them. And hopefully if we can develop the industry a little further then some of the local business guys can really capitalize on that, and take it forward. So the fact that it was a new technology relatively and a new industry, that was more an incentive for us to be involved. (01)

However there are negatives to working with unproven technologies such as described by the same interviewee, "the operating costs, for maintenance and how often it needs to be uplifted is still an unknown at the moment" (01). The life expectancy of the device, because it is a prototype, is also uncertain. Funding is also difficult to obtain because of the risk level. Tidal technology compared to wind technology, as described by an interviewee involved in a renewable energy project on Shetland,

> Wind is a proven technology. Banks know that they can run it through an existing model and they pretty much know what to expect. They know the technology is reliable. Underwater renewables, it's all fairly new. (02)

This quote illustrates one of the challenges for niche expansion because they involve a radical innovation which inherently tends to involve a certain amount of uncertainty around technology performance and therefore investor confidence for investing in these types of developments.

The NYDC has been contacted by other communities about the tidal project who are interested in potentially developing a similar type of tidal community project. The advice from the NYDC highlights that the tidal project is risky as an income generator, which is often an important aspect for communities looking to develop renewable energy. For the NYDC, the tidal project was described by an interviewee involved in a community development organization on Shetland as,

> It was never intended to be an income generating project and most of the communities who contacted the NYDC were interested in seeing it as an income generator. Well the NYDC advice was that that was probably a risky strategy and it could easily lose money. Hopefully we are going to do alright but it certainly is never going to bring us in a lot of money so if that had been our aim then it would have been almost a disaster. (01)

The purpose of the North Yell Tidal project was not simply for income generation but rather as a way to aid moving the tidal energy industry forward through a research and development project, particularly in Shetland. One interviewee, a member of a Scottish Government agency, noted that there are particular issues that arise from a community organization being involved in a research and development type renewable energy project rather than an income generating project,

> There's obviously some interesting issues coming out of that the North Yell Tidal Project, there's some interesting dichotomies between getting communities involved in effectively research and development projects as opposed to them buying a piece of technology that is proven and you get profit. (09)

Although there have been many challenges faced during this project and partnership a positive to this is the learning, as one interviewee a member of a Scottish Government agency on Shetland stated,

> There will be a lot of lessons learned through the project about how you partner, how community groups partner with developers and how you get the best outcome for each party. (06)

The North Yell Tidal Project is an important scheme as a niche because many lessons have been and are still to be learnt from its development as the first project of its kind in terms of ownership and technology combination. The next section describes the Isle of Yell (where the North Yell Tidal scheme is located) as a periphery to the Shetland mainland.

7.2. Isle of Yell as a Periphery

The Isle of Yell is located to the north-east of the Shetland mainland and is linked by a ferry that runs between Toft and Ulsta. It is the largest of the North Isles of Shetland at 133 square km (83 square mi) with dimensions of 27km (17mi) long and 11km (7mi) wide (Shetland Islands Council 2004). Yell is composed of mainly grazed moorland. The more fertile land is located around the edges of Yell and the largest peat deposits in Shetland are located in the centre (Shetland Islands Council 2004). The settlements on Yell tend to be located near or on the coastline. The largest islands that surround Yell are uninhabited including Bigga, Hascosay, and Linga. The population of Yell was 957 in 2001, which was a decline of 9.3% relative to 1991 (Shetland Islands Council 2004). The population has risen slightly since 2001 to 966 in 2011 (National Records of Scotland 2013). There are a range of challenges of living on Yell some of which are related to the location of Yell in relation to the Shetland mainland where the Sullom Voe Oil Terminal and Lerwick (the only town on the Shetland Isles) are located. One interviewee who lives on Yell and is involved in a community development organization on Shetland described some of these challenges,

> Although the ferries are expensive and under threat it is an achievable commute to the oil terminal. That is a very positive thing that people have the opportunity, but on the flip side of that there is less incentive for people to live on Yell and the wages they are paying are very significant and proves difficult for local business to retain employment or compete with the wages. (01)

Some commercial peat extraction in Yell is carried out for the Shetland market but it is limited by environmental constraints (Shetland Islands Council 2004). The Yell Community Council Area Statement (2004) identifies crofting as helping retain its population and that it, "underpins much of the way of life in Yell" (p.3). However crofting incomes have declined in recent years and islanders have responded by diversifying into activities such as the production of crafts or soft fruits (Shetland Islands Council 2004). There is an ice plant located on North Yell in Cullivoe that opened in 1999 and produces 30 tonnes of ice per day that is supplied to the local fishing and aquaculture industries (Shetland Islands Council 2004).

The current local plan that covers Yell and the rest of Shetland is the Shetland Local Plan (2004). This plan informs council land use decisions through a detailed framework for communities, developers, and public agencies. It includes, within the Yell Community Statement, one statement about the potential for renewable energy development specifically for Yell,

> 7.1 Yell's large expanse of remote, open moorland makes it an ideal location for wind turbines. There is also considerable energy potential from wave and tidal sources, particularly in Yell Sound where a pilot seabed tidal

> energy generator has been installed and assessed. (Shetland Islands Council 2004, p.3)

The pilot seabed tidal energy generator was a separate tidal project from the North Yell community-owned tidal project. The pilot project was developed and deployed for short periods by The Engineering Business Ltd (Newcastle-based firm). The device was called the Stingray (150kW). It was the first full-scale tidal stream generator when it was deployed in 2002 (The Engineering Business Ltd 2005). The device generated power by currents flowing over a hydroplane wing that oscillates. This device is different from Nova's tidal device that is an underwater turbine. The Engineering Business Ltd device, the Stingray, was installed for short periods of time in the Yell Sound with the first phase in 2002 with a feasibility study, second phase involved building and installation of the Stingray device, and the third phase in 2003 with the removal and assessment of the device. The pilot project was unsuccessful in that the device did not perform to expected levels that would make it commercially viable and this can be understood as a failed niche.

7.3. Shetland as a Periphery

This section describes Shetland and discusses it as a periphery to the Scottish mainland. North Yell with the North Yell Tidal Scheme niche can be understood as a nested periphery to the Shetland mainland. The Shetland Islands are a subarctic archipelago of Scotland and have the North Sea to the east and the Atlantic Ocean to the west. The archipelago is comprised of over a hundred islands of varying size and of which fifteen are currently inhabited. The total population of the Shetland Islands is 22,400 (Shetland Islands Council 2015). This population has been declining with projections for further future decline and population drift from peripheral communities to the main employment centre and only town in Shetland of Lerwick (Shetland Islands Council 2009a). Shetland's relatively distant location within Scotland affects their development and way of life. This has been described in the, Renewable Energy Development in Shetland: Strategy and Action Plan (2009a),

> Shetland's peripheral location means that opportunities for economic diversification and growth are rare. However, our natural resources have repeatedly given our islands a competitive advantage and encouraged economic activity to locate here. (Shetland Islands Council 2009a, p.1)

This quote identifies how 'peripherality' is a disadvantage because there is limited economic development potential linked to the high transport cost of material imports or product exports and the limited access to labour and markets (Shetland Islands Council 2009a). Shetland is particularly vulnerable to rising oil and gas prices because of several factors including its dependence on ferry and air travel between external islands and to Shetland, dispersed population (car dependence), high cost of living, and climate that requires relatively intensive heating (Shetland Islands Council 2009a). The Renewable Energy Development in Shetland: Strategy and Action Plan (2009a) identifies renewable energy development as a potential way to off-set the 'peripherality' disadvantage through either green energy solutions or lower cost energy solutions.

Many of Shetland's industries rely heavily on primary industries and related resources. The fishing industry has been an important part of Shetland's economy because of its rich fishing grounds (Shetland Islands Council 2009a). Shetland was transformed in the 1970s by the discovery and development of the oil and gas industry in the North Sea. Exploration for offshore oil and gas began in 1970 and the construction for the Sullom Voe Oil Terminal began in 1975. The Sullom Voe Oil Terminal is an approximately 400 hectare site, 46km (29mi) north of Lerwick and is operated by BP Exploration Operating Company Ltd (Shetland Islands Council 2011). The terminal's throughput[69] of crude oil reached a peak in 1984 (at total receipt of 439,434,656 barrels), however this has declined in recent years (Shetland Islands Council 2013). However, BP announced, in 2013, plans for extension of the life of the terminal to 2040 with a £100 million overhaul due to further offshore gas development that will utilise the terminal (Schielhallion development and Clair Ridge project) (Shetland Islands Council 2013). BP also announced plans in 2013 to build a gas "sweetening" plant costing £500 million taking gas from both west and east of Shetland and removing the hydrogen sulphide from

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[69] The amount of oil that goes into the terminal to be processed (not the amount that it produces after processing).

the gas (Shetland Islands Council 2013). Construction on the Shetland Gas Processing plant started in 2010 by Total E&P and Dong E&P, to be operated by Total E&P (Shetland Islands Council 2013). Peak construction required roughly 2,000 workers. This gas plant processes gas from the Laggan and Tomore gas/condensate fields. The Oil Terminal contributed 4.3% of the sectoral output[70] of Shetland in 2010 (Shetland Islands Council 2013).

An Act of Parliament was secured at the beginning of oil and gas exploration by the Shetland Islands Council that gave a percentage of the value of each barrel of oil landed on Shetland as royalties in addition to local taxes. These royalties and other disturbance fees are partially channelled into a Council 'Oil Reserve Fund' (value almost £200 million in 2012) and the Shetland Charitable Trust (reserve of roughly £217 million in 2011) (Shetland Charitable Trust 2011). The Shetland Charitable Trust's purpose is to make grants and loans to benefit the Shetland community. Through these additional funds and the creation of this trust, the potential for the 'resource curse' was trying to be avoided.

In the 1980s aquaculture expanded around Shetland in voes (narrow bays or inlets). Aquaculture makes up 14.3% of the sectoral output (the largest) of Shetland (in 2010) (Shetland Islands Council 2013). Industries experience cycles of downturn and expansion, and Shetland's various industry sectors have tended to compensate for each other; as some experienced downturn, others compensated for this by being more successful. The economy of Shetland has been described as 'fragile' in the Renewable Energy Development in Shetland: Strategy and Action Plan (2009a) because, "our industries are influenced by global conditions and our community has little control over their economic well-being" (p.1). However, the Action Plan also acknowledges that it is these recent experiences of new industries emerging and declining that have benefits for Shetland as, "the lessons we have learned mean that we are well placed to secure

[70] Calculated as the sum of all transactions within the sector as a percentage of all the other sectors on Shetland.

optimum value from another new and emerging industry in our community" (Shetland Islands Council 2009a, p.8).

The owner and operator of Shetland's energy distribution network is Scottish Hydro Electric Power Distribution. Shetland is not connected to the UK mainland National Grid therefore all the fluctuations in supply and demand are controlled from Lerwick (Shetland Islands Council 2009a). The electricity demand on the Shetland Islands ranges from roughly 11MW up to 48MW at peak times with a large portion of the demand from the largest community of Lerwick (Northern Isles New Energy Solutions 2015). Until 2000 fossil fuels powered 100% of Shetland (Shetland Islands Council 2000). The average household electricity consumption in Shetland is twice the Scottish average (at 10,348 kWh per annum) in part because a large number of homes rely on electricity for heating, hot water, and cooking (North Atlantic Energy Network 2016). As of 2010 the electricity produced on Shetland is still largely from fossil fuels which total roughly 93% of electricity production, with the remaining primarily from onshore wind turbines (Scottish and Southern Energy 2010). There are four main source hubs producing electricity that supply Shetland: Lerwick Power Station (67MW installed capacity) commissioned in 1953 diesel-fired station; Sullom Voe Terminal Power Station (100MW installed capacity but produces 22MW) gas powered station; Burradale Wind Farm (3.7MW installed capacity) the only commercial wind farm and is privately-owned; and a number of community-based, small-scale, mainly wind generators as well as the North Yell Tidal Scheme (Northern Isles New Energy Solutions 2015). The Lerwick Power Station provides roughly 52% of the electricity demand on Shetland during a year (North Atlantic Energy Network 2016). However, due to the fact that the station can no longer meet European Union (EU) emission level standards and the aging infrastructure of the Lerwick Power Station, it needs replacement (North Atlantic Energy Network 2016). One of the potential solutions includes a separate Shetland Interconnector project to connect Shetland with the UK mainland. There is also a District Heating Scheme in Lerwick (12MW) fuelled by the local waste to energy plant that provides heat to 400 customers (Scottish and Southern Energy 2010). Shetland has a large amount of renewable energy that could be captured from the various parts of the environment with particularly wind and tidal, which has been estimated to possibly be as high as 10,500

GWh/y (gigawatt hours per annum) with more conservative estimates around 2,200 GWh/y (Shetland Islands Council 2009b).

Unique to Shetland are the powers given through the Zetland County Council Act 1974. This came about because of the oil and gas development beginning in the 1970s. The Act gives the Shetland Islands Council powers relating to compulsory purchase (linked to advance purchase of the land for the Sullom Voe Oil Terminal), created the harbour authority for the territorial sea surrounding Shetland (initially 5km (3mi), later changed to 19km (12mi)), and financial powers linked to borrowing, investing, and business participation. These powers have implications for developing renewable energy, such as for marine renewable energy located within the territorial sea.

Renewable energy development has been described as a priority in various Shetland Islands Council documents. For example in the Shetland Islands Council Corporate Plan 2013-2017 (2014b), there is the priority to, “create and put into practice a Renewable Energy Development Plan 2013-2020 which will look to find a balance between inward investment in the area and local community projects and define Shetland’s proposition as a test site for renewable-energy projects” (Shetland Islands Council 2014b, p.10). There are two actions (4.1 and 4.2) within the Shetland Islands Council Economic Development Policy Statement 2013-2017 (2014a) relating directly to renewable energy development on Shetland. The first action is to, “contribute to national, regional and local policies on renewable energy development” (Shetland Islands Council 2014a, p.22). This is by developing a ‘Renewable Energy Action Plan 2014-2020’ (where the 2014 approved action plan is in place) and support the Strategic Energy Development Group (ongoing). The second action is to, “support research and development projects in renewable energy across the isles, in homes, businesses and community organisations” (Shetland Islands Council 2014a, p.22). This is through grant and investment support for community-scale renewable energy projects, increased renewable energy installed capacity, and development of projects that can connect to the local grid through Shetland’s Northern Isles New Energy Solutions (NINES) project.

The Shetland Islands Council has an action plan for renewable energy development called the, Renewable Energy Development in Shetland: Strategy and Action Plan (2009a). The document informs future economic planning in Shetland even though it is not a formal planning document because it was adopted by the Shetland Island Council Development Committee.[71] The way in which renewable energy as a resource is viewed in this document is as an 'opportunity' rather than a 'certainty' for Shetland. The Strategy views renewable energy development as having a range of potential benefits including in relation to the 'fragility' of Shetland,

> Our goal is to use renewable energy to enhance the quality of life in Shetland for future generations. The partners in this strategy believe that the opportunities for renewable energy development in Shetland offer our community a rare opportunity to reduce our fragility and create a positive step-change in our economy. Furthermore, renewable energy development can secure significant community and environmental benefits in addition to the economic benefits which could be created. (Shetland Islands Council 2009a, p.1)

A set of objectives are included in the document that are centred around: reducing Shetland's power demand through improved energy efficiency, replacing non-renewable fuels with renewable energy sources, creating jobs and new skills through renewable energy related economic activity, obtaining other direct benefits, enhancing community viability for peripheral communities through renewable energy use, and stimulating renewable energy awareness. The document also identifies two main principles that must be part of any development, that there is, "support or engagement from the community in our activities" as well as, "protection of the special qualities and characteristics of Shetland's natural and historic environment" (Shetland Islands Council 2009a, p.7).

The Shetland Renewable Energy Forum (SREF) is a membership organisation meant to meet the objectives and plans from the renewable energy strategy (Shetland, Renewable Energy Development Shetland: Strategy and Action Plan) (Shetland Renewable Energy Forum 2015). Their aim is to help with the development of renewable

[71]The Action plan was initiated through the General Industry Panel and involved consultation with industry, public sector, and environmental agency in Shetland from March to July 2009 (Shetland Islands Council 2009b).

energy in Shetland through providing advice and being a, "coherent voice to be heard in Edinburgh, Westminster and Brussels" (Shetland Renewable Energy Forum 2015). The SREF was active until recently (2014); however the former committee members have considered re-activating it. The SREF was also linked with the Shetland Northern Isles New Energy Solutions (NINES) project that is looking at solutions to the constrained electricity grid on Shetland, particularly examining renewable energy source connection to the Shetland grid and solutions for electricity storage as well as options for once the Lerwick Power Station is decommissioned since it is near the end of its life span (Northern Isles New Energy Solutions 2015). NINES is led by the owner and operator of Shetland's energy distribution network, Scottish Hydro Electric Power Distribution. It is scheduled to last from 2011 to the end of 2016 and has acquired funding from sources including Ofgem, DECC, and Hjaltland Housing Association. NINES aided the North Yell Development Scheme in acquiring its grid connection as noted earlier in the chapter.

7.4. Conclusion

The North Yell Tidal project is an important example of a new form of renewable energy development with the tidal technology which is in the early stages of commercialization in combination with the partnership between a technology company (Nova) and local community (NYDC). The interviews from this research illustrate the issues and dynamics created from being a resource periphery through past resource development of oil and gas to aquaculture. The more recent focus on renewable energy development is shown through the North Yell Tidal Development Scheme and more widely through policy documents such as the Renewable Energy Development in Shetland: Strategy and Action Plan. The North Yell Tidal Scheme is a part of the core-periphery dynamics between North Yell and the Shetland mainland. This is nested within the larger context of Shetland that faces a range of challenges and core-periphery dynamics and processes which are explored through the second case of this study, the Shetland Interconnector discussed in the next chapter (Chapter 8).

Chapter 8.

Shetland Interconnector

This chapter presents the empirical data collected for the second case, the Shetland-UK mainland electricity grid interconnector. The proposed subsea interconnector would connect the currently isolated Shetland electrical grid with the mainland UK grid. This chapter describes the case in more depth than the brief outline in Chapter 5 Methods and presents empirical data from this study. Eight interviews were conducted relating directly to this case and relevant policy documents examined. The previous chapter (Chapter 7 Case 1 North Yell) included contextual information about Shetland and its governance and policy that are also relevant to this case of the Shetland Interconnector.

The chapter begins with a description of the Shetland Interconnector. This is followed by an overview of the current electricity infrastructure on Shetland and challenges related to the increasing amount of electricity produced from renewable energy development. The current renewable energy projects on Shetland are then summarized. This is followed by a discussion of the interconnector's roles with respect to renewable energy development on Shetland. There are alternative forms of renewable energy development on Shetland in contrast to the development of renewable energy with the interconnector that are then briefly explored.

8.1. Shetland-UK Mainland Electricity Grid Interconnector

The Shetland Islands are located 209km (130mi) north of the UK mainland and their electricity grid is not connected to the UK mainland grid (Shetland Islands Council 2009a). However, Shetland is a part of the broader UK electricity market with it being the most substantial non grid-connected electricity network in the UK supplying 15 islands and extending 900 km (559mi) (Scottish and Southern Energy 2010). The Shetland electricity network includes 1,650km (1,025mi) of overhead and underground cables and 13 subsea cables (North Atlantic Energy Network 2016).

There are plans for a subsea high-voltage direct current (HVDC) cable interconnector (600MW) between Shetland (from the Moray coast) and the UK mainland (Caithness) (Scottish Government 2013). The interconnector project involves an underground HVDC cable, a HVDC converter station (at Upper Kergord), and a subsea HVDC cable from Shetland to the Scottish mainland (Caithness). The cable would span 284km (176mi) and be a single circuit (Scottish Government 2013). The interconnector is the responsibility of the grid operator Scottish Hydro Electric Transmission Ltd (SHET). SHET is part of Scottish and Southern Energy (SSE) who owns and operates the transmission grid in the Highlands. As the licensed transmission company SHET, “has to ensure there is sufficient network capacity for those within it seeking to generate electricity from renewable and other sources across a diverse, challenging and remote geographical region” (Scottish and Southern Energy 2013, p.1). SHET is in the process of negotiating planning consents for the cable and converter stations. Outline consent was granted by the Shetland Islands Council in 2011 for the Converter Station at Upper Kergord, and a further application has been submitted by SHET to deal with the conditions specified from the 2011 consent. The interconnector is estimated to cost £600 million (Bevington 2014). An interviewee from a government agency described how, “the government has not made a decision yet if they will help build the interconnector or not or where the money’s going to come from” (06). SHET will submit a ‘needs case’ that outlines the technical and economic justifications for the interconnector to Ofgem in 2016 and the cable could be completed as soon as 2021 (North Atlantic Energy Network 2016). However this was delayed by a year because of uncertainty around the Contracts for Difference (CfD) scheme’s impacts on renewable energy development on Shetland. Previously a completion date of December 2018 had been considered in 2013 (Scottish Government 2013). If the ‘needs case’ is approved, the project will be assessed by Ofgem and a budget will be set for SHET which would be made in 2017.

The proposed Shetland-UK mainland grid interconnector project is linked with the proposed Viking Windfarm (370MW) (described later in this chapter (8.3.5 Viking Windfarm) in more detail). Viking Energy is, “the only generator to have applied for and provided security for a grid connection” for the currently proposed interconnector and therefore would have contractually firm grid access (Scottish Government 2013, p.22).

The Viking Windfarm (370MW) requires the interconnector in the way it has been proposed because it would produce more electricity than Shetland's current electricity demands which ranges from roughly 11MW up to 48MW at peak times (Shetland Islands Council 2009a; Northern Isles New Energy Solutions 2015). Therefore the 'excess' electricity from Shetland's electricity demand could be exported to the UK mainland through the interconnector. The way in which the Viking Windfarm has been proposed means it cannot proceed without the Shetland Interconnector.

8.2. Shetland Electricity Infrastructure

Shetlands current electricity infrastructure and system is facing 'constraints' and grid 'balancing' challenges as renewable energy has been added to the system in Shetland which started in 2000 (Shetland Islands Council 2000). The interconnector would alleviate some of these constraints and balancing challenges to some extent. This is noted in the Renewable Energy Development in Shetland: Strategy and Action Plan (2009a). This plan states that, "the lack of a link to the UK National Grid and limitations within the existing local network are significant infrastructure constraints" (Shetland Islands Council 2009a, p.6).

A number of respondents described how Shetland's renewable energy development is 'constrained' because of the lack of ability to directly export its electricity. As described by an interviewee from a utility company in Scotland,

> Shetland is a constraint by definition because it's on its own and until it's connected to the mainland then it is constrained in a sort of global sense in that it is constrained by its own boundaries. (08)

As this quote describes, Shetland is limited by its isolation and lack of connectivity with respect to electricity. With the current electrical infrastructure and system there are limits to the amount of renewable energy development that can be added to the Shetland electricity grid. However, the current infrastructure is able to deal with the current renewable energy generation on Shetland which is roughly 7% of the electricity production (Scottish and Southern Energy 2010). The same interviewee further stated,

> There isn't a network problem on Shetland, there is nowhere yet where anyone is generating to the point where there is surplus energy and it can't flow to where it's needed because of constraints on our system. But if you were going to do large-scale renewables then that would be a problem. (08)

It is large-scale renewable energy projects such as the Viking Windfarm project and other smaller projects described in the next section of this chapter that present an issue for the current Shetland electricity infrastructure.

Highlands and Islands Enterprise (HIE), as the Scottish Government's economic and community development agency for the Highlands and Islands, has renewable energy as one of their priorities, particularly marine renewables and community-ownership of renewable energy development (Highlands and Islands Enterprise 2016). The limited opportunity for further renewable energy development and the current grid constraints on Shetland has limited the Highlands and Islands Enterprise (HIE) to aid renewable energy development. As described by an interviewee from a member of a Scottish Government agency on Shetland,

> For the whole of HIE renewable energy development is one of the main priorities, but for Shetland what we can actually do we are struggling with at the moment. We are supporting very small-scale community renewable projects but even that is challenging because of the grid constraints. (06)

The small-scale community renewable projects noted in this quote refer to schemes such as the North Yell Tidal Scheme, discussed in the previous chapter as the first case of this study. An interconnector between Shetland and the UK mainland would create an export option for Shetland's excess electricity as described in more detail in the next section of this chapter.

Shetland's electricity grid faces balancing challenges particularly as renewable energy has been added to the system. This challenge of balancing and regulating the electricity distribution network was described as the biggest challenge for Shetland by an interviewee from a utility company in the UK,

> The unique thing about Shetland is that it's not interconnected anywhere else so it's like a mini power station and demand unit all on its own. So the whole thing must be regulated and balanced across the network in a very

> controlled way. You can have large fluctuations and changes in either demand or in generation if you are trying to keep the whole situation stable. That is really the biggest challenge in Shetland. (08)

The fluctuations in power generation from wind are more pronounced in Shetland than on the UK mainland because it is a physically smaller system. There is also a spatial challenge to the development of renewable energy. The distribution of power generation is far more dispersed with renewable energy than traditional electricity generation such as coal, gas, or hydro. This underlines the technical requirements of communication between the production points and overall controller of the system in order for the grid to be balanced. The same interviewee highlights the importance of communication technology and the role of the Northern Isles New Energy Solutions (NINES),

> If you think back to normal power station environment you've basically got everything in the same room where you can control it. What we're trying to do in Shetland is have it spread out everywhere but communications and control become critical. But communications have a cost and that's one of the biggest commercial issues around the whole NINES project is that for some of the very small generators there is not the profitability in the scheme because of the cost of the communication infrastructure. (08)

The NINES project has looked for solutions for the aging infrastructure and electricity grid constraints on Shetland.

8.3. Shetland's Renewable Energy Projects

Within the current network a certain amount of renewable energy in Shetland has already been developed with 7% of the electricity on Shetland produced from renewable sources (Scottish and Southern Energy 2010). There are a range of renewable energy projects on Shetland already constructed and others in various planning phases. These projects are relevant to the interconnector project because part of the argument for the interconnector to be built is that it would allow for additional (to the Viking Windfarm) renewable energy development to occur because this additional electricity could be exported from Shetland. The main renewable energy developments on Shetland include: Burradale Wind Farm, Garth Wind Farm, Fetlar, Shetland Tidal Array, Viking Windfarm, and other projects in earlier stages of development.

8.3.1. Burradale Wind Farm

The largest renewable energy project on Shetland currently operational is the Burradale Wind Farm (3.7MW) which is operated and owned by Shetland Aerogenerators Ltd (Shetland Aerogenerators Limited 2015). Shetland Aerogenerators was formed in 1992 and is locally owned on Shetland. The first three turbines (Vestas V47) (total 2MW) were commissioned in 2000 and an additional two turbines (Vestas V52) (1.7MW) were commissioned in 2003 (Shetland Aerogenerators Limited 2015). The capacity from the five turbines can supply 0-18% of Shetland's power demand. The capacity factor[72] is one of the highest in the world at 52% due to Shetland's strong and consistent winds (Shetland Aerogenerators Limited 2015).

8.3.2. Garth Wind Farm

The North Yell Development Council (NYDC) holds two trading subsidiaries, one for the tidal project and the other for a wind project, Garth Wind Farm. The NYDC investigated developing a small wind farm on North Yell with feasibility work starting in 2003. In 2011 planning permission for five wind turbines (850-900kW each, total 4.5MW capacity) at Garth on North Yell, was given by the Shetland Islands Council. As of 2014 the project was, "just finalizing some legal issues and then we will be looking for funding very soon" (01). The wind project has a much different purpose for the NYDC than the tidal project (North Yell Tidal Project), as described by an interviewee involved in a community development organization on Shetland,

> The Garth Wind Farm is a really important development for us as an income generator. Whereas the tidal turbine was never really envisaged to generate any income, it was meant to give the industry a step up and to encourage local businesses to become involved in a new industry. (01)

This income generation is needed because, "a huge problem is local government or wider government funding which always seems to be getting cut" (01). The project has some

[72] The capacity factor is the ratio of the amount of electricity produced over a given time divided by the amount of electricity that could be produced if running at full capacity. For example with wind energy the wind source is intermittent therefore capacity factors tend to be significantly lower than for other non-renewable sources of energy.

challenges including the grid connection permission the project received that is, “expecting to switch us off 30% of the time which reduces our total income by 30%.... We are lucky that it is still profitable like that but if we get a connection to the UK mainland then hopefully that 30% restriction will be lifted” (01). The interconnector could increase the profitability of existing renewable energy projects such as the Garth Wind Farm because of the restrictions with some grid connection permissions.

8.3.3. Fetlar

The Isle of Fetlar is located north-east of the Isle of Yell. Fetlar Developments was set up in 2008 by the community of Fetlar and is a company limited by guarantee with charitable status. They are developing a renewable energy scheme that is in the process of being installed on Fetlar involving two onshore wind turbines of 25kW each and two thermal stores using water, as well as private wire electricity supply for several buildings. It will be grid-connected however it can run without supplying electricity to the National Grid (The Scottish Government 2014a). Fetlar Developments received support from the Community and Renewable Energy Scheme (CARES) program for a feasibility study and developing the full scheme, as well as support from HIE and local authority funding. Although the project is currently largely reliant on grant funding the plan is to become self-sufficient with time. The project has faced a number of challenges since it started including the Feed-In-Tariff’s (government scheme for subsidizing renewable energy schemes) decrease in price as well as funding changes. The experience was described by an interviewee involved in the project as, “we have been hammered at every step of the way” (02). The project has also been shaped by Fetlar’s location within Shetland’s electricity grid, as described by the same interviewee,

> Ideally we’d like to put up a single big turbine. We had a couple of perspective sites for that but the issue is that our subsea interconnector between Fetlar and Yell couldn’t support the export potential of that turbine. To upgrade the undersea cable would be crazy money. You would have to put up another half dozen turbines to just pay the cost of the cable. That’s really not what I was looking to do… what I was looking for was income generation. So I thought we can use the power locally so we started developing this scheme. It has taken a lot of work to get that through and get funding for that. (02)

This quote illustrates the options Fetlar had for developing its renewable energy, one with upgrading the interconnector from Fetlar to the rest of Shetland, the other without upgrading the interconnector to Fetlar. The existing infrastructure of the National Grid had a significant influence on the type of renewable energy development that took place which resulted in a number of small wind turbines with additional ways to consume and store the electricity locally rather than a single large wind turbine with the purpose for export.

8.3.4. Shetland Tidal Array

The Shetland Tidal Array is a project to build five tidal turbines, each 100kW Nova 100 devices, for a total of 0.5MW in the Bluemull Sound between the isles of Yell and Unst (Nova Innovation 2016). The five devices are expected to power the equivalent of 300 homes (The Scottish Government 2014d). The project involves two companies, Nova Innovation based in Edinburgh, and ELSA, a Belgian energy company. Nova has permits to install the five devices and holds the Crown Estate lease for the specific section of the seabed (Nova Innovation 2014). The first phase of the project involves the deployment of three 100kW tidal devices. Two of the three turbines were installed in 2016 making it the first offshore tidal array connected to a National Grid (Nova Innovation 2016). The NYDC has no direct involvement with the Shetland Tidal Array. However, in the earlier stages of the North Yell Tidal Project there had been discussion of the NYDC being involved.

8.3.5. Viking Windfarm

The Viking Windfarm is a 370MW proposal for a 103 turbine wind farm to be built on the central mainland of Shetland.[73] A map of the layout of the Viking Windfarm is shown in Appendix 6. It could power over 175,000 homes (Shetland Islands Council 2015). This would make it the largest community-owned wind farm in the UK (North

[73] The proposed size of the Viking Windfarm was initially larger than 370MW. The original application for the project was submitted in May 2009 to the Scottish Government for 150 turbines. This was later revised in 2010 to 127 turbines. Permission was later granted in April 2012, for 103 turbines with the remaining 24 denied due to location proximity to the Scasta Airport.

Atlantic Energy Network 2016). The scheme is owned by the utility company SSE (50% stake) and the Shetland community through the Shetland Charitable Trust (45% stake). The Shetland Charitable Trust would receive payments and profits from the Viking Windfarm. The other 5% is owned by the owners of the Burradale Wind Farm, who were brought into the project because of their expertise from developing the Burradale Wind Farm. The Viking Windfarm can be understood as a 'community' wind farm because of the role of the Shetland Charitable Trust. The reasoning behind the project was linked to the community's role with developing its resources as described by an interviewee involved in the renewable energy industry on Shetland, "the idea was, if this is going to be done to Shetland then let's try and get what we can out of it, let's try and do it ourselves" (05).

The Viking Windfarm with its 370MW capacity would supply enough electricity to power roughly 4% of Scotland's total electricity demand (North Atlantic Energy Network 2016). Much of the electricity generated by the Viking Windfarm would be exported from Shetland since the electricity demand on Shetland ranges currently from 11MW up to 48MW (Shetland Islands Council 2009a; Northern Isles New Energy Solutions 2015). However, because of the fluctuation in daily and seasonal winds, the Viking Windfarm would generate less electricity than the demand for electricity on Shetland for roughly 30% of the year (Scottish Government 2013).

The wind farm has planning permission and will apply for a contract under the Contract for Difference (CfD) subsidy scheme in late 2016. If this application is successful, then the project could meet financial close in early 2017 (North Atlantic Energy Network 2016). The Contracts for Difference (CfD) contract would require the Viking Windfarm to become operational in line with the Shetland Interconnector completion dates. The Viking Windfarm would pay a 'use of system charge' for transmission over the interconnector (North Atlantic Energy Network 2016, p.12).

The Viking Windfarm has been controversial in part due to its ownership. The project is described as a community wind farm because of the Shetland Charitable Trust's large stake in the project. However, there are mixed views about the Shetland Charitable

Trust with their 45% ownership of the Viking Windfarm. As discussed in the previous chapter the Shetland Charitable Trust was created in 1976 when the Sullom Voe Terminal, an oil and liquefied gas terminal, began operation. The Shetland Charitable Trust was created to receive compensation from the oil industry on Shetland, which they disburse to a wide range of initiatives including leisure centres, care homes, and the Shetland Museum and Archives. The Trust has spent £248 million since 1976 on the Shetland community (Marter 2011). The Trust has invested £10 million into the Viking Windfarm. Estimates for the amount of community benefit funds from the Viking Windfarm are £1.85 million per year. The 2015/16 budget for the Shetland Charitable Trust was £9.8 million (Riddell 2015). This is a decrease over time from £15 million in 2003 to being brought down to £11 million in 2011 (Marter 2011). Fieldwork indicated that there are some negative views of the Shetland Charitable Trust due to its history and composition of members.[74] It was felt by some of the community that the Trust's members did not fully represent the views of the community which was noted by an interviewee that is a member of the Shetland community involved in the renewable energy industry (02).

The Viking Windfarm has also been controversial because of its size and location. The project faced a judicial review of the planning permission that was launched by the community group Sustainable Shetland.[75] This was later taken to the Supreme Court, the UK's highest court of appeal, who turned the appeal down in February 2015 with judges also declining the case to be referred to the European Court of Justice. There have also been concerns over the siting of wind turbines within the 2km (1.2mi) guideline for separation distance between wind turbines and the edge of villages, towns, and cities. Wind turbines would not be placed within 1km (0.6mi) of houses. This concern over not following the 2km (1.2mi) guideline was voiced in multiple interviews. One interviewee working for a renewable energy company on Shetland described this as,

[74] The Trust has a board composed of 15 Trustees; comprising seven Councilor Trustees appointed by the Shetland Islands Council and eight Appointed Trustees selected from the Shetland public.

[75] Sustainable Shetland was formed primarily of community members to fight against the Viking Windfarm.

> If people want to put turbines in the middle of nowhere who's going to care. If there are ones near houses or going to cause direct effects than try to take them away. Worst thing is to put them up within this 2km of houses, which is breaking their own guidelines. That to me is just being silly. I am very pro renewables but you have to work with people. That is something that I feel Viking, as a supposed community project, has been sorely lacking. (02)

This quote illustrates how the location of the wind turbines has been an issue along with that the project is only a 'supposed community project'. However, the 2km (1.2mi) separation is only a guideline as noted in the Scottish Planning Policy (2010), paragraph 190,

> A separation distance of up to 2km between areas of search[76] and the edge of cities, towns and villages is recommended to guide developments to the most appropriate sites and to reduce visual impact, but decisions on individual developments should take into account specific local circumstances and geography. Development plans should recognise that the existence of these constraints on wind farm development does not impose a blanket restriction on development, and should be clear on the extent of constraints and the factors that should be satisfactorily addressed to enable development to take place. (The Scottish Government 2010, p.39)

This guideline figure of 2km (1.2mi) has recently come under review. In 2013 a review was conducted for the Scottish Government that explored the evidence and rationale behind the 2km (1.2mi) guideline (Onyango et al. 2013).[77]

The controversy around the Viking Windfarm's ownership, large-scale, and location, have had a large impact on the Shetland community as noted in a number of interviews. The project has been viewed as, "a very unsavoury episode in Shetland's history" and, "whether it goes ahead or not I think it will leave scars" (04) as described by a member of an active community organization on Shetland. Another interviewee who is also a resident of Shetland but employed in the renewable energy industry described the lasting impact the controversy has had on relationships within the Shetland community, "you should be allowed to have different opinions about the wind farm, it

[76] 'Areas of search' refer to areas where "appropriate proposals are likely to be supported" (The Scottish Government 2010, p.39).

[77] The origins of the 2km (1.2mi) separation criterion could not be traced but Scotland has led in its use. The review also explores three policy options for this guideline: retention, increased distance to 2.5km (1.6mi) (due to increasing turbine sizes), and no specific distance but rather a visual impact criterion.

shouldn't mean that your relationships become poisoned but unfortunately that has happened to much of Shetland" (05).

8.3.6. Other Projects

There are plans for other wind farms on Shetland including the Peel Wind Farm and the Energy Isles project (North Atlantic Energy Network 2016). The Peel Wind Farm would be 70MW and located on South East Yell. They are involved in consultations with the local community. The Energy Isles project involves a consortium of 18 Shetland businesses developing plans to develop 150-200MW of wind power on North Yell. Neither of these projects have a formal agreement for capacity on the proposed Shetland Interconnector (which Viking Windfarm has).

8.4. Support and Opposition for the Shetland Interconnector

There has been a range of support and opposition to the Shetland Interconnector project. Support for the interconnector and the Viking Windfarm tends to focus on the economic benefits of job creation and environmental benefits in contributing to Greenhouse Gas (GHG) emission targets. Fieldwork indicated a strong link between the history of economic development (with aquaculture and oil and gas) and hardship on Shetland with support for the Viking Windfarm. This support was linked by an interviewee on Shetland involved in the renewable energy industry to the history of oil and gas in Shetland because on Shetland, "we've always exported our resources" (05), and therefore, "why shouldn't we export our wind energy?" (05). The three quotes below from Shetland residents involved in renewable energy on Shetland illustrate this link between support for the interconnector with the Viking Windfarm and Shetland's history of large-scale resource development. Interviewees (02) and (03) work for different renewable energy companies on Shetland and (06) a Scottish Government development agency manager on Shetland,

> I know people say it is terrible, that they look awful but if you look around Shetland every voe is full of salmon cages, it is not very visually appealing,

> but it makes Shetland a hell of a lot of money and that employs a hell of a lot of people. Don't see anybody complaining about them now. I wasn't overly enthralled with the number of them going in myself but you realize that people are making their livelihoods out it and keeping people in the islands, it is something you ought to put up with. (02)

> Ok money isn't the answer to everything but you need money to survive and Shetland until the oil came along was a dirt poor place. Most Shetlanders had to leave the island and go to Canada, New Zealand, Australia to scratch a living out of desperation or even worse they were evicted by the lairds, the landowners of the day, the Clearances. The older generations of Shetland see Viking as a fantastic opportunity to secure the future for our children and grandchildren. And those are the people who in the 1950s and 1960s had to leave Shetland and go off to the whaling in the south Atlantic or get jobs in the towns or cities… So Viking is about building a secure future for Shetland. (05)

> Shetland's not shy of big industry, thirty forty years of the oil and gas industry being here and we probably have another forty years to go… I think Shetland is very embracing of large-scale industry, it's all about how it is planned and developed and done responsibly. (06)

These quotes illustrate where the support for the Shetland Interconnector and Viking Windfarm focus on the economic benefits and the history of resource development. However there is also a moral argument voiced by an interviewee who is a resident of Shetland involved in the renewable energy industry that,

> Shetland is not going to avoid playing its part in the renewables revolution and trying to tackle climate change, not with the resources it's got, the wind and wave and tidal, it would be ludicrous and selfish of Shetland not to try and do something to tackle climate change when we are going to be affected by it as well. (05)

This moral argument is an example of a way to frame and persuade peripheral areas to develop and export their renewable energy to cores.

Fieldwork indicated that support for the proposed interconnector and Viking Windfarm was also linked to the 188MW portion of the capacity of the interconnector to allow for further renewable energy development on Shetland. The interconnector with its 600MW total capacity would have 188MW of space for other renewable energy to export since the proposed Viking Windfarm would take 412MW.[78] There are potential benefits for small-scale renewable energy development as described by an interviewee involved in a community development organization on Shetland,

> Garth Wind Farm is the only largish wind farm to have a connection permission and it would be unlikely if anyone else could have gotten on. But now hopefully the interconnector comes then other communities can do the same. So it could be very good news for us outlying communities particularly. (01)

This support for the development of an interconnector because of the potential for further renewable energy development is noted in Shetland policy documents. For example, in the, Shetland Islands Council Economic Development Policy Statement 2013-2017 (2014a). This policy statement explicitly states its support, as one of the outcomes/targets to back action 4.2, to aid renewable energy research and development through, "support local efforts to establish an interconnector between Shetland and the UK mainland" (Shetland Islands Council 2014a, p.22). The renewable energy development potential created by the Shetland Interconnector is also noted in the Renewable Energy Development in Shetland: Strategy and Action Plan (2009a). The approach to renewable energy development on Shetland as described in this Strategy and Action Plan is to be done, "just as we do in our main industries of oil and gas, fisheries and aquaculture" (Shetland Islands Council 2009a, p.6). This approach to these other industries on Shetland has been for large exports. The Action Plan also describes how Shetland prioritises potential developments with reference to 'Objective Four',

> Preparatory work can be undertaken now to prepare Shetland for the opportunities that could be created by an interconnector. The interconnector proposed is being constructed to support one specific project [Viking Windfarm]. However, it is widely anticipated that there will be capacity for additional generation within Shetland ... All of the objectives within this strategy should assist this task and future developments should be prioritised which provide the optimum value in terms of economy, community and environmental impacts. Any preparatory analysis of future opportunities may include specific consideration of Objective Four,

[78] The Viking Windfarm is permitted to be 370MW however the Viking Windfarm has 'contractually firm grid access' for 412MW because that was the proposed size for the wind farm when the Shetland Interconnector was initially being planned (Scottish Government 2013).

> enhancing the viability of peripheral communities. (Shetland Islands Council 2009a, p.9)

This quote from the Action Plan notes the importance of objective four for the Shetland Islands which refers to ‘peripheral communities’ and their ‘viability’. It is also described in the plan that the interconnector, “could result in installation capacity of greater wind capacity than the interconnector capacity” and that this may make it, “most economic to export all output where possible, and any output which cannot be exported due to interconnector capacity is used to provide electric heating on Shetland” (Shetland Islands Council 2009a, p.27). This illustrates one vision of the type and amount of renewable energy development the interconnector could make possible.

The income from the Viking Windfarm through the Shetland Charitable Trust is also a motivation of support for some residents of Shetland. The Viking Windfarm would generate income for the Shetland community through payments to the Shetland Charitable Trust. The trust has experienced budget changes over time as the funds they receive and investments change with a peak of investments of over £300 million in 1999 to a low of £134 million in 2003 (Marter 2011). This decrease in funds for the Shetland Charitable Trust has led to a search for alternatives as described by an interviewee working as a manger for a renewable energy company on Shetland described,

> The amount of money we earn from the oil industry for community funds has dwindled a lot and we’ve been looking for something else, for a new golden goose that could lay golden eggs. (05)

These funds are important for Shetland as they fund initiatives such as leisure centres, care homes, and the Shetland Museum and Archives.

Although there is support for a Shetland to UK mainland interconnector there were also concerns expressed in interviews. Much of the opposition by the Shetland community is focused on the Viking Windfarm proposal and its scale, which requires the interconnector in order to be feasible for development. The justification for the scale of the wind farm is linked to the interconnector as described in two interviews, with (04) a member of an active community organization on Shetland and (05) a renewable energy manager on Shetland,

> Viking Windfarm's size is to justify the interconnector cable, not necessarily because the landscape can accommodate that. This is the number of turbines they require to make the interconnector financially viable. (04)

> That is one of its problems, is the scale, but the scale is required, you can't have the one [interconnector] without the other [Viking Windfarm] unfortunately. (05)

The interconnector and the Viking Windfarm are connected projects because, as described by a Scottish Government development agency manager interviewee, "unless you've got a big project to justify the investment of an interconnector you're going to struggle*"* (06). Other community concerns identified in interviews for the interconnector tended to be related to cost and around who would bare this cost. The community group, Sustainable Shetland, argues against the Shetland Interconnector because, "without a cable we have more chance of developing appropriate and sustainable wind farm development" (Sustainable Shetland n.d.).

8.5. Alternatives

Renewable energy in Shetland could be developed in a range of different forms, with or without interconnectors. The interconnector and associated Viking Windfarm offer one pathway to developing Shetland's renewable energy however there are many other possibilities. The dominant view expressed in the interviews was that the interconnector and Viking Windfarm is the only viable way for Shetland to develop its renewable energy on a large-scale. One interviewee who is a manager for a Scottish Government development agency described the reasoning behind this view of the interconnector being the only viable option,

> Some people would argue we should just build an electricity generation system that serves the local people, that there's plenty of energy around here. We could just build turbines, or a limited number of turbines and other renewable energy devices just to support industries and people living in Shetland and we shouldn't look at a big export market ... but I don't know where you would get an investment for that because institutions and developers are wanting to make money ... so really the only way it is probably going to happen is if we go with the model of being able to export

> some of our energy and derive some sort of community benefit from that. (06)

This quote illustrates how the current regime shapes the types of future energy developments particularly through the way projects receive funding. Schemes such as renewable energy developments need to be profitable within a privatized market system (regime) and this shapes the form in which these developments are proposed and made feasible under current conditions.

Shetland's main policy document relating to renewable energy development, Renewable Energy Development in Shetland: Strategy and Action Plan (2009a), discusses the interconnector and renewable energy. The Action Plan notes two options for developing further renewable energy: one without an interconnector and the other with an interconnector. One option is to increase the electricity demand within Shetland. This could be achieved by having electricity replace other fuels or other clean energy technologies that do not require the electricity network to be improved. Hydrogen is identified as a potential way to store and export renewable energy. Orkney has been looking to develop hydrogen storage and electric vehicles as short term storage options to better use the constrained wind energy (The Scottish Government 2013a). However Shetland could also increase electricity demand through producing higher value products which is not noted in the Action Plan. The other option is to export electricity such as through an interconnector. The Action Plan describes the opportunities as,

> There will be opportunities to develop renewable energy projects 'off-grid' but the attractiveness of Shetland as a location for investment is diminished without a grid connection. (Shetland Islands Council 2009a, p.6)

This quote illustrates how the requirements of the existing regime shape what types of development are feasible under certain conditions. The need to 'attract' investment for these types of schemes narrows the possibilities for development. For example, the interconnector could be built with public money to allow for only small-scale renewable energy development and export. However with an interconnector, Shetland would be directly linked with the UK mainland National Grid which would mean they would be directly competing with other energy generators in the market from the UK mainland.

There is still competition for Shetland renewable energy developments even with Shetland not connected through an interconnector for renewable energy investment and funding such as for subsidies (Shetland Islands Council 2009a).

8.6. Conclusion

This case of the proposed Shetland Interconnector illustrates how a National Grid infrastructure project enables certain forms of renewable energy development in a periphery. Without the interconnector, a certain amount of renewable energy has already been developed on Shetland, (7% of electricity produced is from renewables) which has mainly been wind-generated but there is a large amount of further renewable energy that could be developed (Scottish and Southern Energy 2010). The potential for an interconnector to be built between Shetland and the UK mainland is a major project that would drastically alter the constraints on Shetland's electricity grid. Large-scale renewable energy projects such as the Viking Windfarm (370MW) could be built if there was an interconnector along with additional space on the interconnector (600MW total) for other renewable energy developments to export electricity (Scottish Government 2013). However, renewable energy development on Shetland could take a different form from the large-scale renewable energy development and export potential the interconnector presents.

Chapter 9.

Pumped Hydro Storage: Cruachan and Coire Glas

The third case of this study is the proposed Coire Glas Hydro Scheme located in the Highlands, in combination with the Cruachan Hydro Station in Argyll and Bute. These schemes were briefly described in Chapter 5 Methods. The Coire Glas Hydro Scheme is a proposed 600MW pumped hydro storage project by Scottish and Southern Energy (SSE). The Cruachan Hydro Scheme (440MW) is well established in that it has been in operation since 1965 and it was important in developing reversible pump storage technology. Scottish Power, the operator of the Cruachan Scheme, is considering increasing the installed capacity to more than double its current capacity. Coire Glas and Cruachan use similar technology (pumped hydro storage) and are both looking to proceed to development or expand due to current regime and landscape pressures. Therefore the Cruachan Hydro Scheme can act as a proxy case for the Coire Glas Hydro Scheme. A total of six interviews were conducted in direct relation to these cases.

The empirical data collected for these cases are presented in this chapter along with contextual information about the relevant systems. This chapter begins with a description of the Cruachan Hydro Station including information about the local policy relating to renewable energy in Argyll and Bute where Cruachan is located. This is followed by a description of the Coire Glas Hydro Scheme and policy information relating to renewable energy in the Highlands. Then the role of pumped storage in the UK and how it has evolved over time is discussed.

9.1. Cruachan Hydro Power Station

The Cruachan Power Station is a pumped hydro storage power station that was opened in 1965. It is located above Lock Awe, the third largest freshwater loch in Scotland, near Oban (Liébana Villela 2015). Cruachan was built as part of the Awe Scheme by the Hydro-electric Board which included two conventional and self-contained hydro stations, at Inverawe (25 MW) and Nant (15 MW) however, as Payne (1988) describes, the "centrepiece was the Cruachan pumped storage project" (Payne 1988, p.231). It was the first high head reversible pumped storage hydro scheme in the world (Munro & Ross 2011). The installed capacity (440MW) is equivalent to supplying over 225,000 homes (Scottish Power 2011). The Cruachan Power Station is owned by Scottish Power however the Hydro-electric Board originally operated the station until the privatization in the 1990s of the UK's electricity industry (Institution of Mechanical Engineers 2012).

The construction of the Cruachan Power Station took place between 1959 and 1965, and involved roughly 1,500 workers during peak construction and excavation of 220,000 m^3 of rock and soil (Scottish Power 2011).[79] At the time of construction the Cruachan Power Station was described as a 'major civil engineering project' (Scottish Power 2011). Its original purpose was described by an interviewee (an engineering manager for an energy company in Scotland) to be linked to nuclear energy development because pumped hydro could,

> Fit in with the nuclear build program that was going on at the time. Big nuclear stations can't increase and decrease their load very quickly… there are peaks and troughs in demand and this is what Cruachan was built for. To soak up the spare capacity or to supplement it. (13)

Another one of the impetuses for developing pumped storage in the late 1950s described by Payne (1988) was,

> The increasing expense of conventional hydro schemes. Pumping seemed to offer the possibility of providing the storage needed to ensure firm output from peak load hydro plant at a much lower capital cost than the construction of large dams. Furthermore, by its need for electrical energy, pumped storage plant was capable of improving the performance of the thermal plant that produced that energy. (Payne 1988, p.231)

Fulton (1966) describes the development of the Cruachan scheme and how it was possible because capital costs were kept low, due to physical landscape features (e.g. high head), and reduction of the long-term system costs. The Cruachan site has desirable physical features with a high head (height and angle between the upper and lower

[79] During the construction of the power station and dam 36 individuals died (Liébana Villela 2015).

reservoirs) and was integrated into the system of hydroelectric projects within the Loch Awe district shown in the map of Figure 21. Fulton (1966) describes how the capacity of the total Awe scheme, "was comparable in scale with the large thermal plants with which it was destined to work" (p.221). Fulton (1966) carries on to state,

> Although this escalation in size was of a similar order to that which had produced a significant reduction in cost for thermal stations, it was apparent from the first that, if the capital cost of Cruachan were to be kept in line with ever larger thermal plants, every opportunity would need to be taken in the design stage to keep down the cost of that development. (Fulton 1966, p.221)

In order to keep the costs low Fulton (1966) describes how this was in part achieved through the development of a reversible hydro pump which would remove the need for separate pumps; a pump for the purpose of pumping water up to the higher reservoir, and a separate turbine for power generated from water being released to the lower reservoir. Until the Cruachan Power Station, separate pumps had been characteristic of all high-head pumped storage projects (Fulton 1966). Leading British manufacturers in hydroelectric machinery were invited to develop the dual purpose pump-turbine technology for the Cruachan project (Fulton 1966). There was an 'extensive programme of research' by Boving & Co as well as the Electric Company to experiment to develop the reversible pump for Cruachan (Payne 1988). They were able to produce efficiencies through test models of 79% for the combined generating-pumping operation (Fulton 1966). The overall efficiency of the scheme including transmission lines is 75% (Payne 1988). The capital costs saved from requiring a single pump rather than separate ones, was roughly £1 million during the time of development (Fulton 1966).

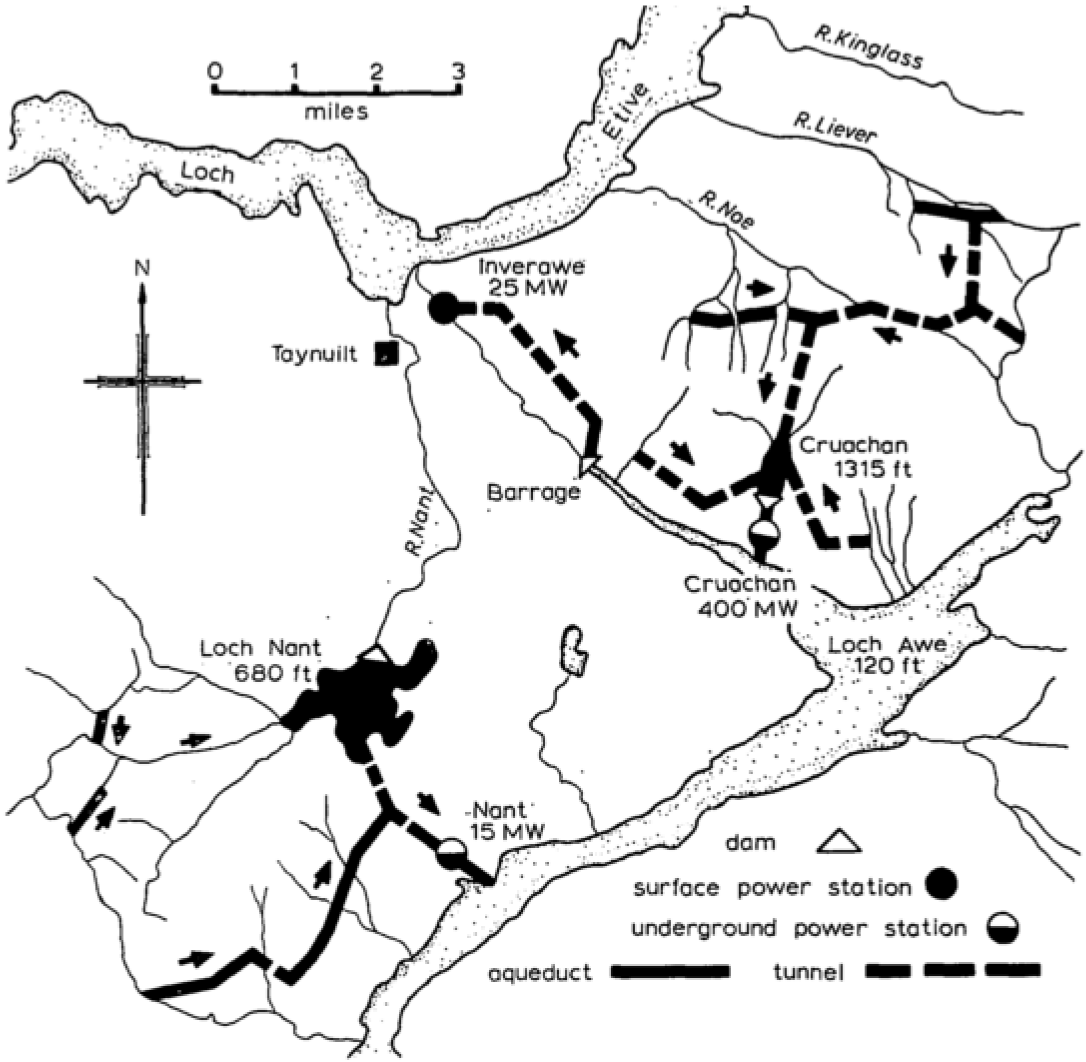

Figure 21 Map of the Cruachan pumped storage scheme and the conventional hydroelectric plants at Inverawe and Nant (Source: Fulton 1966, p.221).

Cruachan's infrastructure includes a power station located in a chamber within Ben Cruachan.[80] The reservoir is located on the side of Ben Cruachan and there are shafts from the reservoir and to Loch Awe via four turbines. There is a network of tunnels and pipes totalling 19km (12mi) in length to divert stream water into the upper reservoir (storage capacity of 10 million m^3) (Nelson 2013). Roughly 10% of the annual output is attributed to rainwater from the above catchment area (Scottish Power 2011). Cruachan's

[80] This location is because of the limited space along the slopes of Ben Cruachan (*Cruach na Beinne*), due to the trunk road to Oban and railway line, along with concerns over the visual impacts particularly of the pressure pipelines on the hillside (Fulton 1966).

upper reservoir can be filled in 16 hours by the reversible hydro-pumps (Liébana Villela 2015). The reservoir can hold enough water for the power station to run for 22 hours of power production (Liébana Villela 2015). However there was a requirement for the reservoir to maintain an emergency supply reserve of 12 hours as Black Start capacity to Longannet Power Station (2.4GW coal-fired power station) (Liébana Villela 2015). [81]

Cruachan operates as a pumped hydro power scheme. Cruachan is currently one of four pumped hydro storage stations in the UK (Argyll and Bute Council 2009). Water can be pumped from Loch Awe into the reservoir during times of low electricity demand and this makes up the majority of Cruachan's power output source at roughly 90% (Scottish Power 2011). As is common with pumped hydro storage schemes, the Cruachan Power Station is a net consumer of electricity because the majority of its reservoir water source is from pumping water from Loch Awe located below the reservoir (Scottish Power 2011). This is cost effective because electricity prices fluctuate with demand, therefore electricity prices are cheaper during times of low demand, and rise with high demand. Pumped storage is able to adjust its power output relatively quickly (dispatchable) with Cruachan able to be in standby and then to full production within two minutes (Institution of Mechanical Engineers 2012). This is a particularly useful attribute for balancing the grid.

The role of Cruachan as a pumped hydro storage scheme has changed over time since its construction. An interviewee who is a manager for an energy company in Scotland noted that this was affected by markets, which "have changed over the last fifty years, Cruachan is going from a supporting function through to now a very fast acting support of unpredictability in the market" (13). This current unpredictability of the market was linked by two interviewees to the expansion of renewables compared to the original role of Cruachan to which was to absorb excess nuclear power from the National

[81] A black start is when a power station needs electricity in order to start generating power if starting from completely turned off. Pumped storage (or a hydro plant) can start generating this power for larger power stations to act as their black starter because hydro stations need relatively little initial power to start generating electricity (the intake gates need to be opened and the generator excited).

Grid. Interviewee (14) is a manager within a power company in Scotland and (13) is an engineering manager for an energy company in Scotland.

> Nuclear is a very predictable base load, so you know every night there's going to be an excess of so many MW baseload generation. And then you can build your model around that. We're looking at a world where we know there is a certain amount of wind capacity available to generate in Scotland. But what we don't know is when it is going to be windy, you know maybe a week ahead. (14)

> The advent of all of the solar and wind turbines has added a degree of unpredictability to the market. So there are demand peaks but it depends if the weather is there to meet those same times of demand. It really becomes more tricky. (13)

These quotes illustrate how the development of renewable energy has created more unpredictability in the demand for electricity from Cruachan as other forms of energy production (renewable energy) are developed and have weather dependent production levels. The changes in demand from the market place has further implications for Cruachan and its infrastructure as described by an engineering manager for an energy company in Scotland,

> As the market changes the way Cruachan operates changes to meet it. In doing so there are often new challenges, new maintenance problems. So everything is operating well and reliably by operating in a certain way but then we start operating in a slightly different way all together which pushes the plant parameters which can mean you end up with a component that was nice and reliable being unreliable. So you have to go in there and make modifications… the cavern itself hasn't really evolved but the machines have been changed along the way to kind of suit the changing market we live in. (13)

Cruachan's changing role has also been noted in the literature by Nelson (2013) who states that, "as this wider energy context and the interplay of wind generation and demand continues, Cruachan's value to the grid is increasing" (p.63). The change in market demands has led to Scottish Power carrying out a two year feasibility study on whether to increase the Cruachan Power Station's capacity to as high as 1,040MW, which is more than double its current capacity of 440MW (Scottish Government 2014). This would involve increasing the cavern space and expanding the capacity of the upper reservoir. This expansion would take roughly seven years to construct and two to three years to acquire the necessary planning consents. It is unclear whether the expansion project will go ahead, as one interviewee who works for an energy company in Scotland stated, “the issue for Cruachan 2 is how you finance that” (13). This expansion proposal has led to strong statements such as in a press release by the Scottish Government (2014) that, “Scotland could be on the verge of a new generation of hydro power to rival the revolution in the glens which saw electricity taken to the Highlands in the 1950s” (Scottish Government 2014, p.1).

Cruachan faces challenges as its role in the electricity market changes over time. The key challenge of aging facilities identified by an interviewee that is an engineering manager for an energy company in Scotland,

> The key challenge is Cruachan is old. These new contracts are challenging us in different directions, putting pressures on things that were maybe 40 or 50 years old have been unstressed are now being stressed so that different mechanisms are starting to come out. Equally there have also been changes to the operators, the human part of things. (13)

An example of one of these technical challenges noted by the same interviewee was that the 40-100MW Fast Firm Response Contract that meant Cruachan reduced their minimum stable generation for one of their machines from 50MW down to 40MW leading to increased stress on the machinery (cavitation on the runner[82]).

> The contract for this 50MW to 40MW shift is lots of money and profit. The cavitation on the runner created by this shift can be replaced, we can weld it, we can send a welder in there to throw some metal back at it and grind it back off and make it look like a new runner and that costs tens of thousands of pounds and we are getting an awful lot of money for this so it becomes a consumable item. Before you looked after your asset, you never said, let’s depreciate it over five years and buy a new one. So things become consumables instead … but to do the repair work may mean your machine is unavailable for a longer period of time. (13)

This quote illustrates how changes in market demand have implications for technology and infrastructure as they have different stresses on them when used in different ways, such as by decreased power output of a hydro turbine.

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[82] Runners are the blades that rotate when fluid passes through the turbine.

The Cruachan Hydro Power Station received an Institution of Mechanical Engineers' Engineering Heritage Award in 2012 which looks to recognise significant mechanical engineering artefacts, locations, collections, and landmarks (Institution of Mechanical Engineers 2012). The award was presented to the Cruachan Power Station, "to mark the fact that it was the world's first high-head reversible pumped-storage power plant" (Institution of Mechanical Engineers 2012). Since Cruachan is the first high-head reversible pumped storage scheme, they are often contacted by other schemes globally. As described by an engineering manager for an energy company in Scotland,

> Cruachan was used as a bit of a blueprint for the planet, so some of the stuff we have still installed, people are having problems with across the globe and people find out and drop me an email, how did you fix that?... They are not a competitor when they are several thousand miles away. We try wherever possible to have some technical dialogue with Dinorwig and other stations but the commercial world is growing and the grey area between it being commercial and technical is starting to get sharper. So it becomes more difficult to talk with these people. (13)

This quote shows how concern over competition leads to less information sharing and the 'commercial world is growing' as the electricity market is becoming more interconnected which in turn increases competition.

The Cruachan Pumped Hydro Scheme is located in the Argyll and Bute Council (*Comhairle Earra-ghàidheal agus Bhòid*) area (Argyll and Bute Council 2009). Renewable energy within the Argyll and Bute Community Plan 2009-2013 (2009) is described as holding 'the greatest opportunities' with it being one of the council's four main priorities (Argyll and Bute Community Planning Partnership 2009). There is a Renewable Energy Action Plan 2010 to 2013 (2009) which is a working document developed by the Argyll and Bute Community Planning Partnership (CPP) as a key action from the Argyll and Bute's Community Plan (2009). The Argyll and Bute Renewable Energy Alliance (ABRA) is a group of public and private sector partners, and their role is to assist with implementation of the plan.[83] The purpose of the Renewable

[83] ABRA includes: Argyll and Bute Council, Scottish Government, Highlands and Islands Enterprise (HIE), Marine Scotland, Scottish Power Renewables, Scottish and Southern Energy, The Crown Estate, Scottish Natural Heritage, and Skills Development Scotland.

Energy Action Plan 2010 to 2013 (2009) is to aid renewable energy development towards their vision which is that, “Argyll and Bute will be at the heart of renewable energy development in Scotland by taking full advantage of its unique and significant mix of indigenous renewable resources and maximising the opportunities for sustainable economic growth for the benefit of its communities and Scotland” (Argyll and Bute Council 2009, p.1). The plan describes its context as having, “not been developed in isolation but reflect[ing] and promot[ing] renewable energy development ambitions which are being pursued at the International, European, UK and Scottish levels” (Argyll and Bute Council 2009, p.5). The plan sets out that it will be reviewed annually to examine progress.

The Renewable Energy Action Plan 2010 to 2013 (2009) identifies advantages and challenges for renewable energy in the region. The ‘competitive advantage’ outlined in the Action Plan is described to be due to a number of factors including the, “world-class track record of innovation in renewable energy” (Argyll and Bute Council 2009, p.8). Examples of this include the Cruachan hydro scheme, the LIMPET (world’s first commercial wave power scheme on Islay), Isle of Gigha community-owned wind farm, and the Community Windfarm Trust Funds.[84] However there are ‘weaknesses’ identified in the Action Plan include,

- constraints as a result of limited grid capacity and charging regime
- lack of distinct regional Argyll and Bute identity and limited national awareness of area and its significant attributes
- remoteness and fragile island-based communities – cost of service higher and delivery options reduced and lack of economies of scale
- lack of capacity of communities in terms of utilities, services, infrastructure and housing to “scale-up” quickly and fully exploit economic opportunities (Argyll and Bute Council 2009, p.14)

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[84] Other competitive advantages outlined in the Argyll and Bute Renewable Energy Action Plan (2009) include: “unique and signification mix of renewable resources and renewable technologies”; “key infrastructure, harbours, ports and airports, for “opening up” the Irish Sea and Western Seaboard for offshore renwable”; investment into Campbeltown/Machrihanish; communities “willing to embrace the opportunities” of renewable energy; the Scottish Association for Marine Science in Oban; the region is close to the Central Belt of Scotland and Ireland, “ideally position for supply of electricity to large urban areas and to provide on shore infrastructure facilities to service the marine renewable industry”; “a culture of collaboration with local and national partners”; “a track record of making things happen”; and “proactive and forward looking Third Sector” (Argyll and Bute Council 2009, p.8–9).

This is just a selection of the weaknesses identified in the Action Plan. Many of these ‘weaknesses’ are common attributes of peripheries.

The Renewable Energy Action Plan 2010 to 2013 (2009) notes that Argyll and Bute are aware, “of the role that we have to play in assisting the EU, UK and Scottish Government in meeting their renewable energy targets” (Argyll and Bute Council 2009, p.4). The Action Plan also identifies some ‘threats’ to their renewable energy development relating to higher level policy and governance,

- National policy overlooks significant renewable energy opportunities of the area e.g. does not consent required grid infrastructure.
- Lack of joined up government at the local and national levels.
- Communities do not benefit from the development of the renewable energy industry and feel excluded from the benefits and the development process.
- Availability of public investment to address insufficient capacity (skills, housing, transport, utilities) to facilitate step change.
- Other areas are prioritised in terms of national focus on renewable energy at the expense of Argyll and Bute.
  (Argyll and Bute Council 2009, p.14)

These threats illustrate regime factors that are influencing Argyll and Bute and their development of renewable energy.

9.2. Coire Glas Hydro Scheme

The Coire Glas Hydro Scheme is a 600MW project by Scottish and Southern Energy (SSE) Renewables. The role of the scheme, as described by one interviewee, is to be, “transmission network scale storage” (14) which is storage for the electricity grid at the transmission network scale which is national. It is located at Coire Glas near Spean Bridge, northeast of Fort William, Scotland. The project was given permission to proceed by the Scottish Government in December 2013 (SSE Renewables 2013). If built, it would be the largest pumped storage scheme in Scotland and the cost has been estimated to be £800 million (SSE Renewables 2013). The scale of the scheme as described by a manager within a power company in Scotland is that,

> SSE took a view that with Coire Glas there would be a need to store larger volumes of energy than previously. All of the existing pumped storage projects in the UK are pretty much day to day storage cycles they are designed around. (14)

The primary function of the project is linked to its scale in that it is, "to extract, store and release energy to or from the electricity transmission system as required to help balance supply and demand for power at a national scale" (SSE Renewables 2012, p.1).

The Coire Glas project involves a range of infrastructure. The project would include a dam being constructed (roughly 92m (302ft) tall by 650m (2,133ft) long) to create a new reservoir at Loch Coire Glas (*a'Choire Ghlais*) along with an underground cavern power station and underground tunnel system (Scottish and Southern Energy 2014). The station is estimated to be able to run at full capacity for a maximum of 50 hours of continuous pumping or release, with an energy storage capacity of up to 30 GWh (SSE Renewables 2013; SSE Renewables 2012). A map of the scheme is shown in Figure 22. The upper reservoir would be located roughly 500m (1,640ft) above Loch Lochy. It would also involve an outlet from the tunnel system on Loch Lochy, a jetty, administration building, and access tracks to the dam and outlet area (SSE Renewables 2012). This main construction work would be anticipated to last for up to five years with a workforce of roughly 150 people involved on site and an average of 12 permanent staff employed during operation from the administration building. There is an existing hydroelectric power station on Loch Lochy at Mucomir (Gairlochy) that releases water to the River Spean through turbines and there are also floodgates, all controlled by SSE. The Coire Glas development would be prioritized over the operation of Mucomir Power Station however the volume of water passing through the Mucomir Power Station would remain unchanged. The maximum and minimum loch levels of Loch Lochy would also remain the same however the variations within these limits may become more frequent (SSE Renewables 2012).

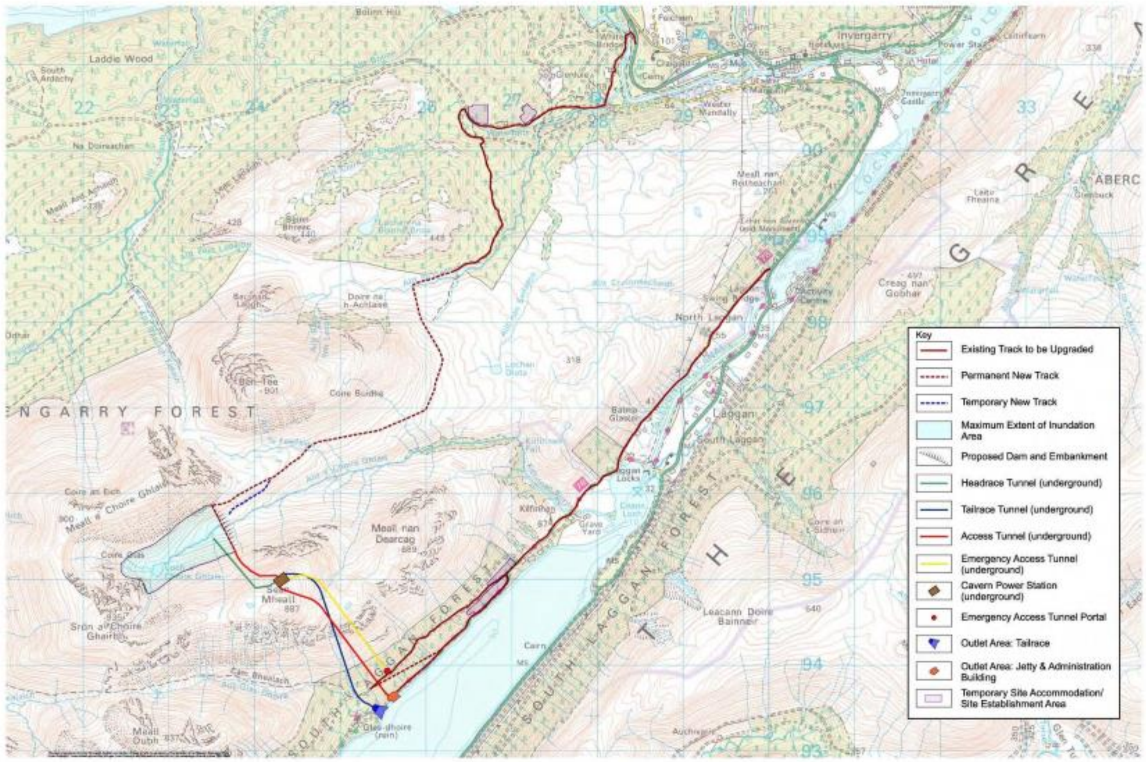

Figure 22 Map of the location plan for the Coire Glas Pumped Hydro Storage Project (Source: SSE Renewables 2011, p.3).

The main proposed benefit from the Coire Glas Hydro Scheme is that it would increase Scotland's on-demand (dispatchable) electricity generation. This benefit is noted in Scottish Environment Protection Agency's (SEPA) judgment of the Coire Glas proposal when outlining the positive impacts of the project,

> The UK currently has approximately 30 GWh of pumped storage capacity. This proposal, which would have a capacity of 30 GWh, would therefore double the existing capacity. This development would therefore represent a large magnitude benefit to maintaining the operation of the UK electricity grid network. The provision of a reliable electricity supply in the UK is of high importance. (SEPA 2015, p.7)

This quote focuses on the scale of benefits as being at the UK level. It is also important to note that pumped hydro storage is a net consumer of electricity that also does not necessarily consume electricity from renewable sources. This made it difficult for SEPA to assess Coire Glas as described in SEPA's (2015) judgement,

> Pumped storage hydro schemes are net users of electricity and normally operate with an efficiency of 90% ... It is not possible to say with any certainty how much of the electricity used to pump water to the upper

> reservoir would come from renewable generation and how much from other sources. However, the basic premise of constructing such a scheme is to facilitate the installation of other intermittent renewables, such as wind turbines, run of river hydro, solar and wave/tidal. At present under certain conditions the amount of electricity generated by intermittent renewables, wind in particular, is more than can be used by the grid and some facilities are required to be shut down. Pumped storage on the scale of Coire Glas would allow this electricity to be stored and released back to the grid during periods where there was little or no wind energy production or when demand for power was particularly high. Consequently the environmental benefit of this scheme has to be assessed in terms of support for grid infrastructure and particularly smoothing out peaks and troughs as the grid comes to rely more heavily on renewable forms of power generation. (SEPA 2015, p.7)

In order to assess the proposed Coire Glas scheme, SEPA took into consideration the, "amount of renewable electricity which is currently lost to the grid due to constraints and which could otherwise have been stored at Coire Glas" and the, "extent to which further development of intermittent renewables which would be facilitated by a pumped storage scheme of this capacity" (SEPA 2015, p.7–8). The figures for the amount of electricity lost to the grid resulting from constraints was measured to be 58.7GWh in 2011 and 45.5GWh in 2012, "figures that are likely to increase over time" (SEPA 2015, p.8). SEPA also took into consideration that pumped hydro storage is the only current proven technology for large-scale storage of electricity. They also considered the fact that there are limited locations within Scotland that are suitable for pumped hydro storage.

There have been objections to the Coire Glas scheme which have centered around the 'severe impact' on the landscape and tourism. There have been objections by parties 'in the vicinity of the development' as noted in the final committee report from the planning office of the Highland Council (2012),

> A significant concern is the impact of the proposed construction works associated with this project including widening of the local access roads which currently serves the local community and the expected impacts arising from the removal of significant volumes of rock from the underground workings to an as yet unspecified final location. These two elements in particular will impact on the current quiet rural amenity which residents enjoy and on which many rely upon for their tourist enterprises. (The Highland Council 2012, p.22)

Although there are benefits to improving access to the local community there are negatives in that the quiet isolation attracts tourists and maintains a certain way of life. The Highland Council (2012) found the impacts to be ‘clear and understandable’. Also, that there will be,

> Considerable benefits with this type of project and strong support for such investment within Government and Council policy. The history of the Highlands is one that includes the development and operation of hydro electricity. Such investment will have impact to the local and national economy both in the short and long term both positive and negative. There will be an adverse impact on the local landscape, including an area designated as a Special Landscape Area. These adverse impacts will be significantly more pronounced during the construction stage than the subsequent operational stage. (The Highland Council 2012, p.23)

The John Muir Trust has been particularly vocal about the expected landscape impacts on an area they describe as having ‘high wild land characteristics’ (John Muir Trust 2012). They also argue that hydro pumped storage is a non-renewable scheme where the loss of local wild land is not justified because it is not a net generator of energy (John Muir Trust 2012).

The Coire Glas scheme has support and planning approval however it is unclear whether the project will go ahead. Since planning approvals have already been obtained, it was described by a Scottish Government environmental regulator interviewee as, “not an environmental constraint stopping them from proceeding at this point in time” (15). A final investment decision by SSE has not yet been made over whether to proceed with the Coire Glas Scheme due to some commercial and regulatory challenges around transmission charging for pumped storage as well as a need for a long-term supportive regulatory framework and public policy (Scottish and Southern Energy 2014). There is a lack of support mechanisms for pumped hydro storage because these schemes do not qualify for the Renewables Obligation (RO) (described in Chapter 6 Existing Energy System). SSE is lobbying for policy changes in order to make the Coire Glas scheme ‘financially viable’ as described by an interviewee, who is an energy company development manager,

> What we need is policy to change, recognize there's value in storage and that storage provides a service to the nation that will have a net benefit on energy security and certainty. What we are saying is that pumped storage is expensive to build, very very difficult to predict the markets we are operating, and we need a safety net as it were… We have got to a point where it [energy policy] has become an inhibitor, it is inhibiting us from going forward and we are now pushing back to policy saying, we need some policy change to allow us to go forward… Our argument is we perceive the nation needs this, 'you need to catch up with that', is what we are saying to DECC [Department of Energy and Climate Change]. We see this as required but they haven't seemed to grasp that yet and if they have grasped it then they don't understand yet that it won't get built under the current framework. (14)

This unpredictability of market conditions and lack of certainty being a barrier to new pumped hydro storage developments is also noted in SEPA's judgement for planning approval,

> It is difficult to compare this [Coire Glas scheme] with conventional hydro schemes as the economic benefit is derived from the price differential between the electricity used to pump water to the upper reservoir and the prices for the electricity which is generated. These figures vary according to market conditions and are difficult to predict. However, the current estimate for the construction of the scheme is in the order of £800 million. Assuming that the scheme would not be regarded as being economically viable unless the investment could be recovered within a time scale of 10 years this infers a financial return of around £80 million per year. (SEPA 2015, p.6)

This quote illustrates the difficulty of predicting the potential income from a pumped hydro scheme because the scheme both buys and sells electricity to the National Grid, unlike most other forms of energy production. With planning approval in place it is dependent on policy and regulatory changes on whether SSE will proceed with the Coire Glas Hydro Scheme.

The Coire Glas Scheme is located within the Highland Council area. There are 30 large hydro developments within the Highland Council area that are 'long established' and 15 smaller, more recent hydro schemes (The Highland Council 2006). There is a policy document, the Highland Renewable Energy Strategy and Planning Guidelines (2006), which was developed by the Highland Council (*Comhairle na Gaidhealtachd*) to supplement the council's existing policies in order to, "provide guidance and direction for Council decision and developers' plans" (The Highland Council 2006, p.2). The Strategy is a non-statutory document and includes a strategic environmental assessment that examines the development option's implications. Pumped hydro storage schemes are mentioned only once within the Strategy as having similar planning issues as run-of-river and other hydro schemes. It is acknowledged that, "future developments are unlikely to reach the scale of existing schemes except in a few circumstances" (The Highland Council 2006, p.3). The Strategy describes context and potential for renewable energy development in the Highland area,

> Looking to the future the energy scene seems set to change. The increasingly clear coupling of global warming to carbon dioxide emissions is forcing both global and local communities to re-examine their sources and use of energy. The Highlands have particularly abundant renewable resources and a large geographical area over which they could be exploited. This potential is well recognised and the area is now attracting considerable development interest. (The Highland Council 2006, p.4)

The Strategy states that, "the region aspires to remain a key player in the energy sector, and, in particular, that it hopes to be a centre for renewable energy production and to share in the benefits that could arise. It is also recognised, however, that there are differing views about the suitability of renewables, particularly onshore wind developments, in the Highland landscape" (The Highland Council 2006, p.2). These 'differing views' were described as part of, "a range of opinions about the value and acceptability of renewable energy, and during the formulation of this strategy strongly held views were expressed" (The Highland Council 2006, p.2). The Strategy describes how the Highlands already have a significant amount of renewable energy already developed,

> The Highland area already contributes significantly to these targets through the hydro power schemes. A key question remains, however, over the level of new renewable capacity that it is reasonable, or even desirable, to generate in each area of the country. (The Highland Council 2006, p.5)

This quote illustrates the dilemma, from the perspective of a council, of how much renewable energy should be developed in various parts of Scotland in order to meet UK and Scotland level targets.

9.3. Pumped Hydro Storage in the UK

The UK electricity sector is facing the challenge of decarbonisation which is not only a supply and demand challenge, it is also a challenge of energy storage (Wilson et al. 2010). Electrical networks have always needed to have their network supply and demand balanced due to technological limits because otherwise the network infrastructure or equipment connected to the network could be damaged (Wilson et al. 2010). The UK transmission network operator utilizes a combination of different market-based services to balance the network's supply and demand as it varies over time (Wilson et al. 2010). The challenges that further renewable energy generation pose to the UK national electrical grid include the disconnect between the timing of electricity demand and generation (Wilson et al. 2010). One solution to this issue of increased unpredictable renewable energy generation which tends to be produced during times when there is not enough demand to meet the production, is to create more energy storage. Pumped hydro storage is currently the most efficient and available technology in terms of storing electricity and can be deployed large-scale (SSE Renewables 2013). The role of pumped storage as described by an interviewee who is a Scottish Government environmental regulator, "is not a net contributor in terms of energy generation but it is a balancing mechanism that enables development of intermittent renewables elsewhere" (15). Pumped storage capacity can decrease transmission costs in that they, "are able to store excess energy, it allows the transmission system to be sized for the average capacity rather than the peak generation or demand requirement" (Scottish Renewables 2015a, p.3).

The majority of Scotland's current hydropower capacity was developed in the mid-20th century (Nelson 2013). However as Nelson (2013) describes, the "expansion in the last 25 years has been under the high profile renewable agenda" (p.232). There are four UK pumped storage schemes currently with a total storage capacity of roughly

27GWh: Ffestiniog, Cruachan, Foyers, and Dinorwig (Scottish Renewables 2015a). Ffestiniog (360MW, 1.3GWh), situated in north-west Wales, was commissioned in 1963 and is run by First Hydro (owned by International Power and Mitsui & Co.). Cruachan (440MW, 10GWh), located in the Highlands of Scotland was opened in 1965 and is operated by Scottish Power (Spanish parent company of Scottish Power is Iberdrola). Foyers (300MW, 6.3GWh), in Inverness-shire on the shores of Loch Ness and has been a pumped hydro storage scheme since 1974. It is owned by SSE and is in the midst of a £8 million refurbishment (SSE Renewables 2013). Dinorwig (1728MW, 9.1GWh) is within North Wales' Snowdonia National Park and was constructed in an abandoned Dinorwig slate quarry. It became operational in 1984 and is run by First Hydro. This makes a total of roughly 2,800MW of pumped hydro storage capacity in the UK (Parliamentary Office of Science and Technology 2008). As described by an interviewee who is a manager within a power company in Scotland, these four pumped hydro storage schemes, "are a legacy" and, "they are all private owners now because the energy network was deregulated and privatized in the 1990s" (14). However, as described by the same interviewee, these projects were,

> All built with government money, by the centralized energy back in the 60s, 70s, 80s. So they were part of a strategic decision by government to build capacity and redundancy and flexibility to the system. We now have this deregulated system where private enterprise is building generation capacity and government has to incentivize things, different technologies, by providing support to those. (14)

Payne's (1988) book, The Hydro: Study of the Development of the Major Hydroelectric Schemes Undertaken by the North of Scotland Hydroelectric Board, describes this period of hydro development in Scotland when the current pumped hydro schemes were built, largely by the North of Scotland Hydro-Electric Board (NoSHEB) with the aim to develop hydroelectricity in the Highlands of Scotland. With Tom Johnston as chairman of the NoSHEB (from 1946) Johnston, as described by Payne (1988), was,

> Intent on reversing the effect of decades of Highland neglect. No matter that he failed to attain his most optimistic purposes; no matter that economists told him and his associates that the necessary capital investment would produce a bigger yield in other fields of endeavour elsewhere in the United Kingdom; no matter that the Board was initially vilified for disturbing the

> fish, despoiling the desolate grandeur of the glens, and submerging the grazing of the sheep and the stag – harnessing the latent power of the waters and making low cost energy available for the people of the Highlands was a laudable objective, and one that was attained. Of course, it could not go on. Eventually the cost of it all was added up, and with that peculiar arithmetic that ultimately transforms hopes and aspirations into arid symbols in a cost-benefit analysis, further conventional hydro and, a little later, pumped storage schemes were halted. (Payne 1988, p.248)

There has been no new pumped storage developments built in the UK over the past thirty years (Scottish Renewables 2015a).

The financing of pumped hydro storage has been described by Foley et al. (2015) as ‘complicated’ within new liberalized markets even though it is viewed by grid operators as a ‘strategic key asset’. Pumped hydro storage schemes are ‘infrastructure intensive’ and, as Scottish Renewables argues, “have significant capital costs associated with them due to the large proportion of specialist underground construction and dam works, long construction period and site specific electrical and mechanical components” (Scottish Renewables 2015a, p.3). Hydro developments require nearly a decade to build due to their infrastructure which creates complications with financing, “since the long lead times for a Pumped Storage project from development to operation could be as much as ten years, future market certainty is a significant risk throughout the development process” (Scottish Renewables 2015a, p.3). This long lead time in combination with National Grid balancing agreements, which are less than five years long, means that agreements cannot be set for new pumped storage plants which can take ten years to build and an operational life of at least fifty years (Scottish Renewables 2015a). An interviewee (a manager within a power company in Scotland) noted there is also, “no energy policy that is driving investment for something that isn’t going to operate for ten years’ time” (14). The payback periods for capital intensive projects, such as pumped hydro storage, are long and therefore unattractive to whole-sale electricity companies who are focused on short to medium payback periods on investment (Foley et al. 2015; Parliamentary Office of Science and Technology 2008). The life spans for hydro projects are relatively long and uncertain depending on maintenance. This is described in the context of Cruachan by an interviewee who is an energy company engineering manager, “hydro is typically very difficult to finance anyway because they don’t have a life span as such ….here [Cruachan] there isn't a closure date, never has been since the thing was built" (13). All these factors make, "long term investment decisions more difficult as revenue is less clear" (Scottish Renewables 2015a, p.4).

Pumped hydro storage developments face regulatory and policy challenges to make them financially viable in the current electricity market system. Pumped hydro storage does not qualify under the Renewables Obligation (RO) and is not recognised in the Electricity Market Reform (EMR) framework. For hydro pumped storage, "there is no mechanism available to enable the necessary investment decisions in new Pumped Storage schemes to be taken and allow the development of projects to be taken forward" (Scottish Renewables 2015a, p.4). The proposed Coire Glas hydro scheme is an example of a large pumped storage development that has received planning approval but is waiting for a final investment decision because of the regulatory framework and policy which SSE currently views as a barrier. Pumped hydro storage's main revenues come from, "arbitrage between prices at peak and off-peak demand; provision of balancing services; capacity payments available under EMR [Electricity Market Reform] arrangements, but no specific mechanism which recognises the wider benefits of pumped storage" (Scottish Renewables 2015a, p.3). The concern for investors as described by Scottish Renewables (2015a) is that, "forecast income from these three activities combined is insufficient to support investment and that the inherent benefits to consumers and the electricity system are not suitably rewarded" (p.4).

The major competitors to electricity storage are demand-side management technologies and conventional fossil-fuel reserves (Parliamentary Office of Science and Technology 2008). However there are plans to build further pumped hydro storage projects within the UK. As Nelson (2013) describes, "enabling the efficient integration of other renewable technologies, peaking and pumped storage hydropower have a heightened role in supporting a low carbon generation mix, seen through the renewed consider of the technology ... the recent 600MW Coire Glass proposal and the moves to increase the capacity of Cruachan" (p.49). SSE Renewables has had an Environmental Statement produced for another pumped hydro storage project apart from the Coire Glas Project, called the Balmacaan Pumped Storage scheme at Loch Ness within the Great

Glen which would also have a 600MW installed capacity. An application for consent has not yet been submitted however SSE Renewables 'retains the option' to develop the Balmacaan project. SSE claims that,

> The Development is in broad conformity with relevant national, regional and local planning policies. The proposals could be considered an important subsidiary of the renewable sector and could provide a valuable contribution to the national energy mix. (SSE Renewables 2012, p.21)

As discussed earlier in this chapter, Scottish Power is looking to expand the Cruachan Power Station's capacity from 440MW to as high as 1,040MW (Nelson 2013).

The current interest in pumped hydro storage is shown through the proposed pumped hydro schemes and expansions by both Scottish Power and SSE. Based on the current proposals for various pumped hydro schemes, an interviewee who is a Scottish Government environmental regulator described how it shows that, "the electricity companies are clear that pumped hydro storage is something that they envisage being necessary into the future but the constraint is actually the cost of building that and the return on that investment" (15). Although there are a number of potential pumped hydro storage developments in the UK, Scottish Renewables argues in their Pumped Storage Position Paper (2015a), that "continued progress in developing such projects is reliant on a satisfactory and supportive long-term public policy and regulatory framework being in place to allow commercial developers to confidently take investment decisions on their plans" (Scottish Renewables 2015a, p.1).

9.4. Conclusion

This chapter presents the case of the proposed Coire Glas Hydro Scheme and proxy case of the Cruachan Hydro Station. The Cruachan scheme exemplifies the changing role of pumped hydro storage as renewable energy is developed and increases the unpredictability of electricity generation. The increased need for energy storage because of the disconnect between the timing of energy production and consumption has led to the identified need for more pumped hydro storage and the proposals of the Coire Glas Hydro Scheme and the expansion of Cruachan. However, industry is lobbying for increased policy support and regulatory framework changes for pumped hydro storage to make these types of projects more ‘financially viable’ for developers.

Chapter 10.

Analysis

This chapter presents the results from the analysis of the three cases that make up the collective case study of this research. The three cases, North Yell Tidal Scheme, Shetland Interconnector, and Coire Glas/Cruachan Pumped Hydro Storage Schemes, represent parts of the electricity sociotechnical system from production, transmission, and storage. This sociotechnical system is examined as being in the midst of a transition towards renewable energy sources. The transcripts from the 22 semi-structured interviews and various policy documents related to the cases were analysed using NVivo for themes. The detailed methods for this analysis are described in more depth in Chapter 5 Methods.

This chapter addresses three of the research questions for this study identified in Chapter 1 Introduction. The chapter, Chapter 4 Towards an Analytical Framework, directly addressed the first research question. The three research questions addressed in this chapter are,

2. What are the **sociotechnical transition dynamics** during a sociotechnical transition?
3. What are the **core-periphery dynamics** during a sociotechnical transition?
4. How are **sociotechnical transition dynamics** interlinked with **core-periphery dynamics** in the case of Scotland's transition to renewable electricity?

This chapter begins with an analysis of the case study sites in relation to the analytical framework presented in Chapter 4 Towards an Analytical Framework. The next section addresses research question 2 above by examining the sociotechnical transition dynamics that are being created by some of the policies, targets, and legislation that are influencing the renewable energy transition in Scotland. An important dynamic of the renewable energy transition is the move towards community and local ownership which is also discussed. This is followed by question 3 where the relationship dynamics between cores and peripheries over time as processes of peripheralization are examined by discussing the relational, multi-dimensional, and multi-scalar processes. Then question 4 is addressed by discussing the history of energy development in Scotland as well as niche and renewable energy development in relation to transition-periphery dynamics.

10.1. Analytical Framework

This section applies the analytical framework presented in Chapter 4 Towards an Analytical Framework to the case study sites of this study. These case study sites include the North Yell Tidal Scheme (Chapter 7), Shetland Interconnector (Chapter 8), Cruachan and Coire Glas Pumped Hydro schemes (Chapter 9). These cases represent parts of the wider sociotechnical electricity system from production, transmission, and storage. The analytical framework was developed alongside the collection and analysis of the data collected for this study. The first research question of this study is addressed through the development and presentation of this analytical framework. The framework brings together the concepts of sociotechnical transitions (Chapter 2) and resource peripheries (Chapter 3) to create a more geographically sensitive model for understanding new resource peripheries. The framework extends initial work by Murphy and Smith (2013) who initially connected these concepts and applied them to an examination of wind energy projects in Scotland. In relation to this framework the concepts of 'embedded' and 'multi-scalar' periphery-core relationships and processes are also applied as a way to conceptualize and examine the dynamics around resource peripheries within the sociotechnical transition.

The analytical model presented in Chapter 4 Towards an Analytical Framework is represented in Figure 12 and it extends the MLP by incorporating the processes of peripheralization and centralization. In order to better show how the case study sites from the electricity system fit within this framework an adapted version of this framework is shown by Figure 23.

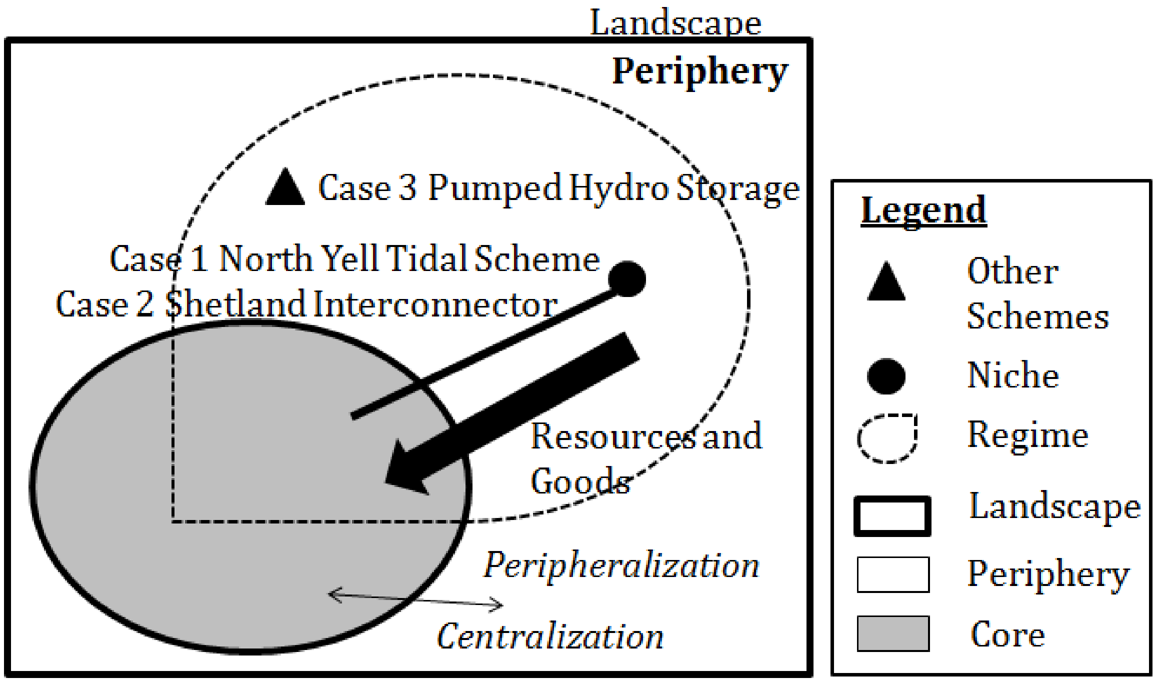

Figure 23 Analytical framework adapted to include the three cases of this study.

Figure 23 illustrates how the analytical framework fits with the empirical cases of this study. The first case, the North Yell Tidal Scheme, is a niche located in the periphery. The Shetland interconnector links the North Yell Tidal Scheme to the core. The third cases of Cruachan and Coire Glas hydro schemes are a part of the electricity system with a storage function and are located in the periphery. The electricity sociotechnical system in the UK is in the process of transitioning. Figure 23 highlights certain aspects of this transition by focusing on the geography and processes of peripheralization and centralization. The empirical evidence from this study illustrates these processes and relationship dynamics being created.

The first case, the North Yell Tidal Scheme, can be understood as a niche located in the periphery as shown in Figure 23. The location of the North Yell Tidal Scheme in the periphery is relatively common with renewable energy niches however niches can also develop in the core. Although the North Yell Tidal Scheme is located in the periphery it is connected to the core through the second case of this study, the proposed Shetland Interconnector. It has also involved forms of resource making as parts of the environment have new values placed on it such as with various forms of renewable energy including tidal energy. This involves uneven development from the enclosure and commodification of resources which is noted as reproducing the classic core-periphery dynamics by Bridge (2010). Resource peripheries have often experienced past processes of resource development involving peripheralization and centralization as shown through the cycles of ‘boom and bust’ resource development. This resource curse type of development is a characteristic of Shetland’s past resource developments of aquaculture and oil and gas described in more detail in 11.2.1 Resource Making. This type of resource development is in a sense re-enforcing the power dynamics that are characteristic of resource peripheries. Renewable energy development in peripheries can be viewed as an income stream that can lessen the negative aspects of being a periphery such as processes of outmigration. Another aspect of peripheralization is shown through the sense of ‘vulnerability’ described by resource peripheries as changes take place to the regime and landscape. This is noted with the North Yell Tidal Scheme later in this chapter. Although renewable energy development can be a large income generator for communities, these developments are reliant on policies and subsidies that create the market opportunities for these types of developments to be viable in our current market system. This adds to this aspect of vulnerability for resource peripheries that are dependent on certain subsides. This sense of vulnerability may be increasing as local economies become more interlinked with national and international economies which can lead to increased green grabbing as the green agenda for more sustainably sourced energy is imposed on resource peripheries (noted in more detail in 11.2.2 Green Grabbing).

The Shetland Interconnector is represented by a line in Figure 23 between the core and periphery. The primary flow of resources and goods are transported from the periphery to the core. The proposed interconnector would connect a portion of the periphery to the UK mainland in terms of the electricity system. This proposal would have important transition-periphery dynamic implications as the green agenda for renewable electricity more directly imposes pressures and power dynamics change potentially increasing the vulnerability and peripherality of the resource periphery. The Shetland Interconnector proposal has come about as landscape pressures emerge around the green agenda for more renewably sourced electricity. This green agenda has involved imposing certain values and needs on the peripheries. Resource peripheries are experiencing the development of renewable energy which is a part of a larger sociotechnical transition to renewable energy. Peripheral locations such as Shetland and North Yell are becoming further resource peripheries in relation to energy and are in a sense reproducing the power dynamics created by past resource developments. In Shetland this can be seen with the oil and gas industry as well as non-energy industries such as aquaculture (discussed in more detail in 11.2.1 Resource Making). The Shetland interconnector and the Viking Windfarm are resource developments where the green agenda is imposing certain values and needs on the periphery leading to potentially further peripheralization. A part of this type of development can involve the resource being 'funnelled' away with little to no consideration for the local people as discussed later in this chapter in relation to the proposed Viking Windfarm. This is added to be the lack of power that is a characteristic of resource peripheries and is noted in 10.2.3 Niches and Renewable Energy Development. Further renewable energy development on Shetland is restricted by the current infrastructure and local energy demand (discussed in 11.3.2 Interconnector Infrastructure). The Shetland Interconnector could lead to centralization of its renewable energy development. There are processes of centralization with the development of Shetland's wind resource as shown with the Viking Windfarm (370MW) proposal (discussed in 11.3.1 Resource Development). It is in some sense a way of developing the wind energy on Shetland in a centralized way with the interconnector to the mainland as the export link. In contrast, a decentralized development of the wind energy could occur through alternatives such as smaller scale developments with more diverse ways of storing and exporting the electricity. The interconnector also increases the scale of demand and brings the needs of all of Scotland and the UK more directly linked to Shetland and in a sense imposed on Shetland as described in 10.2.1 Multi-scalar. The scale of development with respect to the Viking Windfarm is justified by what is framed as the 'need' to export the electricity to support national targets and justify the cost to build an interconnector between Shetland and the UK mainland. The proposed scale of the Viking Windfarm is to contribute to meeting the whole of Scotland's energy demand rather than for the local Shetland scale of demand.

The third cases are represented as triangles in the periphery in Figure 23, the pumped hydro schemes of Cruachan and Coire Glas. These cases are a part of the electricity transmission infrastructure as forms of energy storage. A limited amount of hydro power has been developed in Scotland since the boom of hydro development during the post second world war period however there are proposals such as for the Coire Glas Pumped Hydro Scheme. There is also the proposed expansion of the Cruachan pumped hydro scheme. These pumped hydro schemes proposals and expansion proposals are specifically to meet a certain scale of demand which is at the UK-level rather than the regional or local levels. This is a part of the trade-off between national benefit and autonomy as well as forms of green grabbing. However, pumped hydro storage tends to empower and support further renewable energy development that produces weather dependent (not including tidal or geothermal) and meet short-term fluctuations in demand (discussed in 11.1.1 Technology's Political Qualities). The development of these schemes supports a specific vision for the electricity system that requires large-scale electricity storage as part of a large system. This involves processes of peripheralization and centralization between the peripheries and cores. A key aspect is that as these processes of peripheralization and centralization occur over time areas can de-peripheralize or re-peripheralize. There can also be multiple peripheries and cores with a multi-scalar and nested character.

The current electricity system is being transformed through renewable energy development as the direction of energy flow and the shape of the system is changing to these new locations of production. These changes include the development of transmission and storage infrastructure. These developments create uneven multi-scalar dynamics as this transition occurs within cores and peripheries.

The transition-periphery dynamics shown in the analytical model (Figure 12) can also be understood to be multi-scalar and embedded. These multi-scalar core-periphery relationships are nested within each other with processes of peripheralization and centralization represented by the arrows as shown in Figure 14 (in 4.4.2 Multi-scalar Core-periphery Relationships). Therefore, multiple core-peripheries relationships and dynamics can be present at the same scale encapsulated by a periphery or core. To illustrate how these multi-scalar core-periphery relationships are present with the case study of the electricity system, an adapted version of Figure 14 is shown in Figure 24.

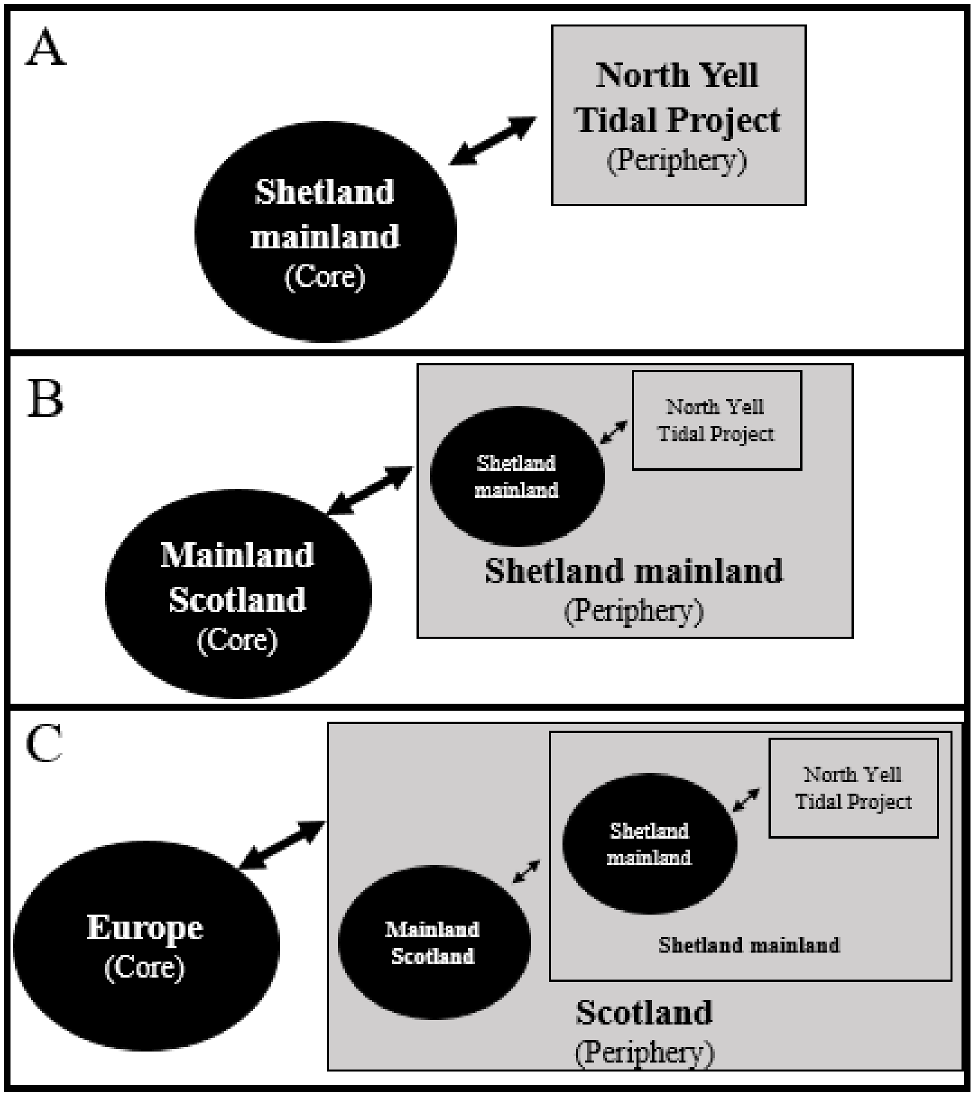

Figure 24 Multi-scalar core-periphery relationships at the scales of the North Yell Tidal Project, Shetland, and Scotland.

In Figure 24 North Yell Tidal Project can be understood as a resource periphery niche, which is a periphery in relation to mainland Shetland, shown in (A). There is also a core-periphery relationship between all of Shetland and its islands as a resource periphery in relation to mainland Scotland particularly when considering the proposed Shetland Interconnector. The UK has been considered to be a part of the periphery because of the relatively limited interconnection capacity with other European countries electricity grids. There are processes of peripheralization and centralization that take place at each of these various scales. Figure 24 shows a single set of embedded core-periphery relationships but there are more core-periphery relationships and processes than simply that of the North Yell Tidal Project to the Shetland mainland and then Shetland mainland to Scotland mainland. For example with other Shetland Isles such as with the other 14 Shetland isles also connect to the Shetland mainland through the electricity grid interconnectors (for example Fetlar discussed earlier in 8.3.3 Fetlar).

Multi-scalar transition-periphery dynamics are clearly shown through the development of renewable energy in Scotland. These dynamics are particularly evident with the proposed Shetland Interconnector and the Viking Windfarm proposal on Shetland. The proposed Shetland Interconnector would increase the scale of demand and bring the needs of all of Scotland and the UK more directly linked to Shetland and in a sense imposed on Shetland. The flow of electricity across the interconnector would predominantly be from Shetland to the UK mainland and involve processes of centralization and peripheralization. The scale of development with respect to the Viking Windfarm is justified by the 'need' to export the electricity to support national targets and justify the cost to build an interconnector between Shetland and the UK mainland. This is described by an individual involved in the renewable energy industry on Shetland, "to make it worthwhile to have the interconnector means a substantial wind farm and that is what the debate is about, whether it is fit for scale for Shetland" (05). The proposed scale of the Viking Windfarm is to contribute to meeting the whole of Scotland's energy demand rather than for the local Shetland scale of demand as described in Chapter 8 Shetland Interconnector. Without the interconnector renewable energy can still be developed, however it is shaped by the infrastructure to support it. This exemplifies the role that infrastructure such as interconnectors play in terms of creating new power dynamics and pressures on resource peripheries. This scale of renewable energy development in Scotland is creating demand for certain types of electricity storage within the electricity system that is shown through proposals such as the Coire Glas pumped hydro storage scheme and expansion of the Cruachan pumped hydro storage schemes. The scale of these developments are for 'transmission network scale storage' which is at the UK-level rather than the regional or local levels. These multi-scalar processes and dynamics are specifically discussed further in 10.3.3 Multi-scalar.

The analytical framework developed by this study is important in that it highlights the geographical aspects of the sociotechnical transition. More specifically it focuses on the geographical processes that are a part of sociotechnical transitions including peripheralization and centralization. The multiscalar aspect to these processes and relationship dynamics are also highlighted as an important aspect to this analytical framework. This multi-scalar approach to understanding resource peripheries aids in avoiding the criticism of the MLP that its levels tend to be associated with certain territorial boundaries as noted by Raven et al. (2012). It also assists in focusing on the processes, both structural and temporal, occurring within and between the different levels of the MLP. By examining these various scales and how niches and peripheries are embedded within one another, it allows for the complex relationship dynamics and sociotechnical transition processes to be more easily uncovered. There are limitations to the analytical framework applied in this chapter. The key limitations of this framework have been discussed earlier in 4.5 Challenges and Limitations. In the application of this framework there are challenges around identifying the boundaries for each of the MLP levels (niche, regime, and landscape) as well as the scales for each of the embedded core-periphery relationships and processes. Therefore it is important when applying the framework to clearly identify the system and boundaries as much as possible. This can be done more easily with certain systems than others. In this study the unit of analysis is the levels of jurisdiction EU, UK, and Scotland governing authorities as well as the UK market and infrastructure in relation to the electricity system, focusing on Scotland. The empirical cases that represent the parts of the system (production, transmission, and storage) are also clearly noted as well as how the cases fit within the analytical framework, explicitly shown by Figure 23. The framework is also limited by its ability to show other influences as some of these relationship dynamics and processes are potentially context dependent and shaped by these factors. There is also the aspect that these relationships dynamics change over time and it is difficult to represent these changes and processes in a framework. However, the analytical framework highlights the important aspect of geography that is often neglected in the study of sociotechnical transitions. This section exemplifies how the analytical framework can be applied. The following sections discuss the various dynamics in more depth including, transition dynamics, core-periphery dynamics, and transition-periphery dynamics.

10.2. Transition Dynamics

There are various dynamics involved in a sociotechnical transition. This section of the chapter addresses the research question,

2. What are the **sociotechnical transition dynamics** during a sociotechnical transition?

These dynamics are created and shaped by the drivers of transitions such as policies, targets, and legislation that are linked to subsidies that support certain technologies and systems. When these subsidies change and how they change have large impacts. There has also been a notable shift towards community-ownership in Scotland that has been supported through policies, targets, and legislation.

10.2.1. Policies, Targets, and Legislation

Policies, targets, and legislation are important shaping factors and drivers for sociotechnical transitions at the regime level however there are many social, technological, economical, environmental, geographical, and cultural factors that shape transitions. They can create opportunities for new technologies to emerge or protect existing systems (Turnheim & Geels 2012). The landscape pressure of climate change has led to a number of international and national agreements, targets, and policies around reducing Greenhouse Gas (GHG) emissions and renewable energy development. Some of these new targets and policies have been key drivers of renewable energy development (Geels & Schot 2007; Murphy & Smith 2013). This is described by an interviewee involved in the renewable energy industry in Scotland,

> A lot of that legislation relating to climate change and decarbonising is a big driver, and carbon targets, carbon price floor emissions trading schemes, all of those have, we see a very practical effect for how the [renewable energy] industry operates and drives and to an extent determines the technologies that come through. I think it is important not to underestimate what government targets do in practice. These big banner targets, obviously

> the Scottish one being particularly strong, do a huge amount to kind of galvanize that industry and build some momentum, so having strong targets is incredibly important to propel the industry forward and that is something that is a big driver in the sector. (17)

Different technologies and combinations of technologies can be supported or encumbered by policies and targets (Turnheim & Geels 2012). Government policies can, "help or hinder certain positions and technologies differently" (17) in the energy sector, for example, as described by the same interviewee,

> The clear Scottish example is this commitment to no more nuclear and the closure of Longannet[85], so you start to suddenly have this landscape where your suite of technologies to pick from is very different. (17)

The Scottish National Party's (SNP) commitment to not developing any further nuclear power in Scotland shapes Scotland's energy system (Scottish Government 2011, p.20). However over time this could change as political priorities and parties in power change. Policies provide industry and the market a certain amount of certainty (Turnheim & Geels 2012). This was described in the context of wind energy development in the European Union (EU) through the, 2009 Renewable Energy Directive, by an interviewee involved in an EU policy level lobbying organization for wind energy,

> The most important piece of law for wind energy and renewables in general in the European Union is the 2009 Renewable Energy Directive which basically set the targets for 2020. So that's basically the most important bit of legislation because it really cleared the way, from that moment on until 2020 investors had a clear understanding of how much renewable energy capacity was going to be installed in each of the member states of the European Union. It was very easy to actually do business because industry precisely knew how much to expect each year in different markets. (20)

This example illustrates how legislation can provide certainty and support for an industry.

Legislation and policies are not static as they change over time due to changing landscape pressures. Policy changes play an important role in supporting or destabilizing industries (Turnheim & Geels 2012). This has been evident with the early closure of the Renewables Obligation (RO) and Renewables Obligation (Scotland) (ROS) for new

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[85] Longannet was the last coal-fired power station to be closed (1972- 2016) in Scotland.

onshore wind power projects in April 2016, one year earlier than originally planned. The RO and ROS for large-scale solar PV were also closed early in April 2015. The decision for these early subsidy closures were made by the UK Government. These recent energy related policy and subsidy changes have large implications for renewable energy developments in Scotland. These changes came about after the election of the UK Government in 2015 of a Conservative majority (previously a Conservative-Liberal Democrat Coalition). Some of the implications of these changes are described by an interviewee from a Scottish Government agency,

> We have had a significant change with the new Westminster Government coming in just over a year ago [in 2015]. The UK made significant changes to the support mechanisms for renewables which has had pretty dramatic effects on the onshore wind industry and paradoxically currently is causing a boom for onshore wind as they desperately try to get their projects completed and so in the contexts of the Highlands and Islands what we are seeing is a lot of projects being built out, a very busy time for civil contractors but what we are also seeing then is pretty much a cliff face for projects, particularly for onshore wind and small-scale hydro over the next few years. (22)

The changes to subsidies have created a ‘boom-bust’ type effect on the industry as developers try to complete developments before the new end of subsidies. This ‘cliff face’ has come about as subsidy supports are ended abruptly rather than slowly decreased over time. The UK’s ranking in the Ernst and Young country attractiveness index has fallen from 5th in February 2014 to 13th in May 2016 (Ernst & Young 2014; Ernst & Young 2016). This is largely due to the increased uncertainty and decreased investor confidence from the subsidy changes.

There is a dichotomy between the priorities and political will in the Scottish Government and the UK Government in relation to renewable energy. One interviewee involved in the renewable energy industry described this political will dichotomy,

> The political will is here in Scotland where it might not be in England. But because these schemes are UK-wide schemes, it applies equally throughout the country. (18)

As the interviewee (17) also involved in the renewable energy industry in Scotland described, the reason for this dynamic is because it is, “a budget being dictated by someone else [UK Government] essentially and changes to support mechanisms are being made outwith Scotland" (17). Unequal power dynamics are a key feature of core-periphery relationships (Brown et al. 2000; Kühn 2015). This geographically uneven disconnect between political will and support for renewable energy creates complex dynamics within the UK. Although the changes to subsidy supports for schemes apply evenly across the UK, there is also an unevenness in the implications of such changes. This is because Scotland provides a disproportionate amount of the renewably sourced electricity production in the UK (based on 2014 levels) for onshore wind (over 60%), wave and tidal (85%), and hydro capacity (over 85%) (House of Commons Scottish Affairs Committee 2016).[86] This is in the context that Scotland has 8% of the UK's population (House of Commons Scottish Affairs Committee 2016).

10.2.2. Community-Ownership

There has been a shift towards community-ownership in Scotland that has been supported through policies, targets, and legislation. Bryden and Geisler (2007) argue that the Scottish Highlands have recently become an epicentre of land reform by embracing local community and culture. Smith et al. (2016) describe this recent development of community energy initiatives as 'flourishing'. Many of Scotland's community energy projects are located in "remote rural areas renowned for their natural beauty and unspoiled character" (van Veelen & Haggett 2016, p.2). The contestation over land ownership and rights is intimately intertwined with the struggle over renewable energy production because of the impacts land has on power and benefits (Mackenzie 2006b). Walker (2008) notes that excluding Scotland, the current UK Government policy as of 2008 was not very supportive of community-ownership with respect to energy production and is argued by some to be due to the lack of adequate subsidy schemes. This shift to community and local ownership of renewable energy in Scotland is different to that of other parts of the UK as described by an interviewee involved in the renewable energy industry in Scotland,

[86] Scotland has a much lower level of solar generation with 3% of the UK's total solar PV capacity (House of Commons Scottish Affairs Committee 2016).

> I think the community dynamic is very different in Scotland than the rest of the UK. The Scottish Government are very keen on more community involvement in renewable sites and developments. Keen to explore possibilities for shared ownership models and community buy-in to sites. It is something the industry is at the very early stage of. (17)

For communities there is also a question of what types of renewable energy technologies are most appropriate to become involved in and in what ways. An interviewee a part of a Scottish Government agency described this balance,

> How quickly and how soon you get a community involved in a research and development project is an interesting challenge. Over the years HIE [Highlands and Islands Enterprise] have worked with communities, for example working with heat pumps put in community centres and helped communities put together pumped storage hydro schemes in places like Foula and Fair Isle to get renewable electricity there to help them move away from diesel generation. It's an interesting challenge to both get technology that works correctly and effectively to ensure there's a legacy there in the community going forward. (09)

This quote focuses on the reliable engineering aspects of appropriate energy technologies for communities. However, there are other factors such as around community preferences. To what extent is it appropriate for communities to become involved in research and development projects under the current support mechanisms is a difficult question. For example tidal technology is at the early stages of being commercialized. The North Yell Tidal Scheme which is community-owned has been successful in terms of being still operational and leading to a larger installation of tidal turbines in the area. However, from a purely economic perspective for communities looking to develop a renewable energy project for income for the community then renewable energy technologies that are less established are riskier and may have lower financial returns (as discussed in Chapter 7 North Yell Tidal Scheme). However, certain funding is available for certain earlier stage technologies. With the North Yell Tidal Scheme, most of the funding came from the Scottish Government's Community and Renewable Energy Scheme (CARES) (£167,763 of the £185,953) (The Scottish Government 2014e). Additionally the purpose of the North Yell Tidal project was not simply for income generation but rather as a way to aid moving the tidal energy industry forward through a research and development project, particularly in Shetland as noted in Chapter 7 North

Yell Tidal Scheme. This demonstrates how community interests in renewable energy development projects are not necessarily financial.

10.3. Core-Periphery Dynamics

Relationship dynamics between cores and peripheries include a range of multi-scalar and multi-dimensional processes. As presented in Chapter 3 Resource Peripheries, the three aspects of peripheralization, which are a refined list based on Kühn (2015)'s five aspects of peripheralization[87], include: relational, multi-dimensional processes, and multi-scalar. The relational aspect is the relationships between locations as processes of centralization, and peripheralization or de-peripheralization (or re-peripheralization) occur. Multi-dimensional processes include the economic, social, political, and communicative dimensions and processes that occur over time. Multi-scalar is the multiple scales at and between which the various processes and dynamics can take place (from global to sub-local). The research question addressed in this section is,

3. What are the **core-periphery dynamics** during a sociotechnical transition?

In order to answer this research question this section of the chapter is organized around these three aspects of core-periphery dynamics: relational, multi-dimensional processes, and multi-scalar.

10.3.1. Relational

Relational refers to the relationships between locations (cores and peripheries) as processes of centralization, re-centralization, peripheralization, and de-peripheralization occur, as noted by Kühn (2015). I suggest that there are also processes of re-peripheralization and de-centralization that can also occur. These various types of peripheralization processes and centralization processes can be seen with respect to the changing urban-rural relationship as well as the power dynamics around policy. Power dynamics are a critical feature of core-periphery relationships (Brown et al. 2000; Kühn

[87] Kühn (2015)'s five aspects of peripheralization are: relational, process centered, multidimensional, multi-scalar, and temporal. These are discussed in Chapter 3 Resource Peripheries.

2015). The relational aspect of peripheralization is exemplified by the changing relationship between cities (cores) and rural areas (peripheries) as renewable energy is developed in resource peripheries. The renewable energy resource is located primarily in the peripheries of Scotland however a large amount of the powers over the development of these resources are held in urban centres. The potential to, "turn the urban-rural paradigm on its head" (09) through the development of renewable energy in Scotland was described by an interviewee who works for a Scottish Government agency,

> What we see here is a really interesting opportunity to kind of turn the urban-rural paradigm on its head. Because the resource is in the periphery, the wind, waves and the tides are at the edge of Scotland, the real opportunity if we do this correctly is create a very strong regional cross-path helping in all aspects of the wave and tidal sector from environment consenting, fabrication, manufacturing, operations and maintenance, right through to decommissioning. So there is actually no need for that to be in the city ... And because we already have significant manufacturing and fabrication opportunities from the oil and gas sector in rural Scotland, there is a real chance to do this and create an opportunity, not dissimilar to what happened in Aberdeen with the deep water oil and gas sector in the north of Scotland. Major companies and institutions are in cities but in regional development terms the ability to create from scratch a brand new sector and by appropriate investment in things like ports and harbours, fabrication facilities, grow university campuses, things like that, there's real long-term opportunity to make sure the focus of the sector is close to the resource. Because what we had, I guess with the hydro board, was the lochs and mountains of Scotland became the object of generation activity but effectively all the intellectual assets and know how was sitting in Edinburgh and Glasgow where operations were HQ'd. And that's I guess where we are trying to turn that on its head. (09)

This vision for renewable energy development shows an emphasis on the periphery and keeping the various aspects of resource development in the periphery rather than in the urban cores. This is in contrast to how the hydro resource was developed in Scotland particularly between 1945-1950s where the periphery was developed as a site of generation for hydro power but the control and operational headquarters were based in the urban cores of Edinburgh and Glasgow. The development of renewable energy, which is largely a peripherally located resource, is changing the flow of electricity from close to urban cores to peripheries to the reverse. In a sense, "the distribution system is setup centre-out distribution and now it’s outer is the centre” (02), described by a member of a Scottish local planning authority interviewee.

There are relational core-periphery power dynamics at the governmental level between the UK Government and the Scottish Government. This unequal power dynamic is one of the defining features of core-periphery relationships (Brown et al. 2000). Energy is a reserved power by the UK Government and the Scottish Government holds powers over granting planning permissions, setting targets, and creating policies (as discussed in Chapter 6 Existing Energy System) (Bergmann & Hanley 2012; Dalglish et al. 2017). Although the Scottish Government’s controls in relation to energy are in a sense “limited powers” (21) as stated by a Scottish Government official, their powers over planning are important because energy developments cannot be built without planning approval. A member of a Scottish local planning authority interviewee described how there is a mismatch between these levels of government in relation to energy,

> There is real clash at the moment… between Scotland and Westminster because a lot of the decisions on energy are actually with the UK Government, Ofgem who will control the level of investment, particularly in grid and the Electricity Act 1989, and it is they who have decided charges on the transmission system, it is they who set up subsidies. (11)

As described above, Ofgem as the government regulator for electricity and gas in Britain holds a large amount of power in relation to renewable energy development because of their control over electricity infrastructure investment, transmission system charges, and subsidies.

The Scottish Government’s restricted powers with respect to energy are demonstrated through the UK level changing of policies and support mechanisms (discussed previously in 10.2.1 Policies, Targets, and Legislation). The UK Government has made recent changes to the subsidy support mechanisms with early closures to certain renewable energy subsidies in the UK (outlined in more depth in Chapter 6 Existing Energy System) that have had large impacts on the renewable energy sector.

10.3.2. Multi-dimensional Processes

Multi-dimensional processes include the economic, social, political, and communicative dimensions and processes that occur over time. The multi-dimensional processes are linked to the rise and fall of spaces. This is opposed to remaining as, "static locations of remoteness" (Kühn 2015, p.374). Spaces change over time as processes of peripheralization and centralization occur. The development of renewable energy in these peripheral locations involves these processes.

There are social aspects to the peripheralization processes and the development of renewable energy particularly for peripheral communities. One aspect is that of public engagement with renewable energy development in peripheral areas. People are becoming more aware of their energy production with renewable energy because of the dispersed and visual nature of some forms of renewable energy, such as wind. One interviewee from a Scottish Government agency described this,

> The sort of advertising that turbines do on hills, it certainly brings energy production much more to the fore, and where energy comes from and how we use it, what we think is an acceptable source of energy. (16)

However with certain forms of energy ownership, such as community versus private ownership, this relationship between the 'advertising' of wind turbines and communities may be different. The ownership type of renewable energy developments plays an important part in these social aspects. There is a shift by the Scottish Government towards community and local ownership particularly with respect to renewable energy (noted in earlier in 10.2.2 Community-Ownership). This has been seen by the exceeding of Scottish Government set targets of 500MW by 2020 of community-owned or locally-owned renewable energy capacity in Scotland (The Scottish Government 2013a) and support schemes such as the Community and Renewable Energy Scotland (CARES) program. An interviewee who is a Scottish Government official described this 'push' by the Scottish Government,

> There is a push at the moment coming out of Scottish Government for community, local energy, big push in fact. Energy consents have changed their name in Scottish Government … to Local Energy and Consents.

> Energy security locally, getting money into communities to improve their longevity, to pin the responsibility back to communities not to rely on these central hubs of community. So that is sort of a direction we are heading in. (16)

This move towards community and local ownership is notable in Scotland unlike other parts of the UK. For other forms of renewable energy such as hydro there are slightly different impacts with respect to public awareness. The same interviewee described,

> The hydro sector, there are now hundreds of hydro schemes in Scotland and SEPA's concern ... is the associated tracks, you can have kilometres of tracks cutting through habitats and have massive landscape visual, cumulative impacts. And land owners and users might want them and have other access benefits but they are a big scar for a lot of these across Scotland. So although the public might not see the energy production they now have landscape littered with tracks that apparently go somewhere and energy is coming from a source that they can only tell from the access associated with it which is a slightly odd one. (16)

As described by this quote, there is this aspect of cumulative impacts and the infrastructure that supports these types of developments. Some renewable energy developments may not be located near rural communities, however the infrastructure that supports them, such as tracks and power lines, can have a larger impact on these rural areas than the renewable energy scheme itself.

There is a political dimension to the multi-dimensional processes of peripheralization particularly in relation to energy. Technologies and technical systems have political qualities and embody certain powers as shown by Winner (1995)'s types of political qualities of technologies (described in more detail in 2.1.2 Systems Perspective). As there are shifts in political will and support mechanisms change over time these shape the types of energy development that occur. Certain technologies are more flexible than others in the way they can be adopted. An interviewee involved in an EU policy lobbying organization described how for the wind industry and likely for other renewables as well that,

> The biggest threat they [wind industry] see for their business is actually regulatory changes. The inner issue is that energy is always political. It does depend on what the government in place actually decides. So that is basically we can either fight or work with that to some extent. The rest as

> an industry we have to accept. What the industry can do is reduce costs. So that is basically the biggest challenge for us as an industry, to get better at what we do. (20)

This quote notes the political nature of energy and renewable energy development. It also describes that the renewable energy industry itself has limited control in that they can reduce costs to make the technologies more financially viable but that is just one aspect of what makes a renewable energy development feasible. Government control over support mechanisms is one aspect of renewable energy development, however there is also the control over planning permission.

10.3.3. Multi-scalar

Multi-scalar is the multiple scales at and between which the various processes and dynamics can occur (from global to sub-local). There are also multiple scales at which renewable energy is being developed in Scotland and is involving processes of peripheralization and centralization. The scale at which these developments are designed for have system-wide implications. One interviewee working for a Scottish local authority described these ‘layers’,

> There are just all the different layers. You’ve got a local community council that represents the hamlets and towns, you’ve got the local authority, you’ve got the Scottish Government, it’s got to work with the Westminster Government, it’s got to work with Europe and the financial regulations that operate across Europe and they have got to work with world trade agreements but also try to commit to the climate change targets. (11)

There are these different levels from the EU, UK, and Scotland, to local communities that influence each other to shape the sociotechnical transition to renewable energy. However, the UK referendum to leave the EU (Brexit) in 2016 has meant the EU level influences will change.

From the EU level, Scotland and its renewable energy is often considered ‘peripheral’. An interviewee from a Scottish Government agency described the potential of developing renewable energy which is located in what is considered the ‘edge around the world’,

> So it’s an opportunity to, in unique economic development terms, use a resource that is at the edge of Europe, at the edge around the world where the resource is. If we can in Scotland actually come up with an economic development model and industrial development model based around the exploitation of renewable energy at the edge then that’s quite an interesting way … to create significant growth opportunities. (09)

This approach focuses on exploiting the resource located in the periphery. There is also the potential to export this energy. Developing this energy also draws into question the role of Scotland and the UK within Europe. There is an emphasis on increasing energy security and increasing the ability to export energy.

The scale of renewable energy development in Scotland is having impacts on creating increased need for larger scale electricity storage. This can be seen with proposals such as the Coire Glas and expansion of the Cruachan pumped hydro storage schemes. The Coire Glas scheme’s scale is ‘transmission network scale storage’. There are various scales of electricity storage however, as described by an interviewee involved in the industry in Scotland,

> We are very clear that what we’re talking about is transmission network scale storage. At the other end of the extreme you’ve got batteries in people’s garages that complement their solar panels on their roofs which is very much domestic scale, and then you’ve got distribution scale storage which might be larger scale batteries and other things that are being discussed like fly wheels and compressed air technology. The challenges associated and risks I suppose that building a big project [Coire Glas] of this massive capacity compared to a few batteries, it is … about going for the economies of scale. (14)

Cruachan is also looking to expand, however there is uncertainty over the scale of this expansion. The way in which Cruachan may be expanded ranges in terms of whether to increase the storage capacity of the dam, or add turbines to increase the amount of electricity that can be produced in a short period of time. These pumped hydro schemes proposals and expansion proposals are specifically to meet a certain scale of demand which is at the UK-level rather than the regional or local levels.

10.4. Transition-Periphery Dynamics

There are complex transition dynamics that occur during a sociotechnical transition as well as core-periphery dynamics. This section brings together the previous two sections of this chapter: transition dynamics and core-periphery dynamics in order to answer the research question,

4. How are **sociotechnical transition dynamics** interlinked with **core-periphery dynamics** in the case of Scotland's transition to renewable electricity?

These interlinked dynamics can be understood as 'transition-periphery' dynamics. This section of the chapter examines transition periphery dynamics beginning by examining some of the energy resource development in Scotland. This is followed by a discussion of peripheries and the development of resources and niches.

10.4.1. Scotland and Resource Development

As a part of the peripheralization processes there have been many types of sociotechnical transitions with respect to energy and other resources. This resource development and exploitation has shaped these peripheries through time. For example in the Highlands there has been the expansion of the electricity network and development of hydroelectricity in the glens. The electrification of the Highlands connected cores and peripheries in a new way with the infrastructure and flow of electricity created by this sociotechnical transition. The current electricity system is being transformed through renewable energy development as the direction of energy flow and the shape of the system is changing to these new locations of production. There is also a history of nuclear power and coal power in Scotland. As an interviewee of a local authority within the Highlands described,

> The Highlands have a huge geography but it also has a huge history in a whole range of different technologies, Dounreay, the experimental unit nuclear power, we've had coal in places like Brora. But we [Highlands] are actually an undeveloped area, in many respects, but we have energy needs and we've also got natural resources. Our hydro being the main stay of that and that was built after the second world war, the hydro schemes, and earlier. (11)

These different energy sources have been captured in different ways over time in the Highlands from coal and nuclear to hydro. Coal powered plants have been phased out with the landscape pressure of the awareness of climate change and the need to decrease GHG emissions. There was also the closure of the last coal fired plant in Scotland in 2016. Nuclear power is also currently being phased out in Scotland since the SNP are against new nuclear power development (Scottish Government 2011). A limited amount of hydro power has been developed in Scotland since the boom of hydro development during the post second world war period however proposals such as for the Coire Glas Pumped Hydro Scheme exist. The expansion of wind development in Scotland has occurred relatively quickly beginning in the 1990s and expanding swiftly during the 2000s. These transitions in the electricity system illustrate transition-periphery dynamics.

Parts of Scotland have experienced a long history of resource development and extraction in various forms. Some view a history of resource development as a justification to have renewable energy development in the same areas. This type of justification by national governments and corporations that communities should accept further development is similar to that of second order nuclear colonialism that has been termed by Kuletz (1998) to describe the justification used for more nuclear testing and toxic waste if they have already done so in the past (Edwards 2011) (discussed in Chapter 3 Resource Peripheries). This type of justification was noted on Shetland with the development of renewable energy there. An interviewee who is a member of the Shetland community and involved in renewable energy development in Shetland described,

> We've always exported our resources, our fish and our salmon and our people, it's not our oil but the oil has been exported via Shetland. Now why shouldn't we export our wind or our wave power? (05)

This quote about historical resource development in a periphery of Scotland shows how histories shape the people and areas. It also shapes the way the people or communities perceive and understand the potential and current renewable energy development in its different forms. These understandings affect what communities determine are appropriate renewable energy technologies and types of development for an area.

10.4.2. Niches and Renewable Energy Development

There are many aspects to the transition-periphery dynamics in the renewable energy transition in Scotland. During a sociotechnical transition, the destabilizing of the regime can create windows of opportunity for niches (Geels 2011), as discussed in Chapter 2 Sociotechnical Transitions. The destabilizing or restabilising of a regime can include core-periphery dynamics. For example, there are relational core-periphery power dynamics at the governmental level between the UK Government and Scottish Government as described earlier in this chapter. The early closure of subsidy support mechanisms by the UK Government with early closures to certain renewable energy subsidies (outlined in more depth in Chapter 6 Existing Energy System) have had large impacts on the renewable energy sector. The impacts of these changes will be geographically uneven and felt within Scotland. An interviewee involved in the renewable energy industry described these policy changes as inhibitors to renewable energy development,

> The biggest inhibitor is just that policy change equals policy uncertainty. And there is no getting around that and getting around that every four years if you've got a new government there's going to be a level of change. But I think the level of change we've seen over the past 12 months has been so incredibly drastic and affecting the industry so deeply that it's a real example of how things can turn around overnight. (17)

As with sociotechnical transitions, landscape features change over time and regimes become unstable to create opportunities for niches to break through and potentially create a transition (Fudge et al. 2015).

An aspect of peripheralization is shown through the sense of 'vulnerability' described by peripheral communities as changes take place to the regime and landscape. This aspect of vulnerability can also be understood as being linked to a community's resilience (Skerratt 2013). As an interviewee from a community organization in Shetland (as noted in Chapter 7 North Yell Tidal Scheme), a peripheral region in Scotland described,

> A huge problem is local government or wider government funding which always seems to be cutting. And we are entirely dependent on these funding

> streams for even the ferry service and links to the UK mainland and everywhere. There is a strike situation on the ferries at the moment on Wednesday mornings they are not sailing until they get a resolution, pay disputes. We still don't have any influence on issues like that (ferry strike) and we always feel very vulnerable. So as much as we can do for ourselves the better... We are always influenced by factors we have no control over. So the more independent or self-sufficient we can become the better and if there is good employment elsewhere that is great but if it falls away again than at least there something to fall back on. (01)

This quote illustrates a sense of lack of power by a peripheral community which is linked in part to access to resources such as funding, as well as control over essential services such as ferries (transport). Part of this lack of control is the sense that they are being 'influenced' by factors that this peripheral community does not have control over. Smith and Steel (1995) have also noted this lack of power felt by peripheral communities that they describe as,

> The people of rural communities see themselves as less able to control their destinies. Community leaders express frustration and powerlessness. They perceive themselves as being controlled by powers far away who neither understand nor really care about the needs of people in resource-based communities. (Smith & Steel 1995, p.52)

Renewable energy development can be done in ways to aid resource peripheries in decreasing the negative aspects of being a periphery and increase their sense of control. This is noted by Dalglish et al. (2017),

> Scotland's current renewable energy transition has the potential to support communities across large parts of the country and to enable them to develop in sustainable ways; but this potential is denied by the exclusion, by-and-large, of the majority of people from decisions relating to the land and from the benefits it can provide. This is a result of a historical process of land monopolisation, the exclusionary effects of which are being perpetuated by those with an interest in the preservation of minority control of the land. (Dalglish et al. 2017, p.8–9)

The historical processes of depopulation with the Highland Clearances (discussed in 6.1.1 History) and more recent preservation efforts are influencing the way in which resource development is occurring.

A motivation for peripheries to develop niches and new technologies can be linked to some of the implications of periphery processes. Peripheries tend to be characterized as experiencing out-migration with populations moving to urban centres as well as low economic activity (Brown et al. 2000). Renewable energy development in peripheries is viewed as an income stream that can lessen the negative aspects of being a periphery such as processes of outmigration. Many rural peripheral areas are experiencing population declines. One interviewee with a conservation charity described how they believed the development of renewable energy in these rural locations would not have a significant impact on making these places more attractive for people to live because there is a larger social aspect,

> Fundamentally wherever you go in the UK and certainly within Scotland you go to the remoter rural areas and people do not want to live there anymore. And how do you change that with one income coming from one small wind farm, a few hundred thousand pounds will not change it, you need a societal change. (12)

However, some peripheral communities are looking to renewable energy developments to decrease some of the challenges of being a peripheral community. The same interviewee went on to describe how some communities feel this type of development would lessen the negative impacts of being in the periphery,

> Some communities are in favour of them. Not because they are actually in favour of the development per say, but they see the benefit of the community fund to them. So when you've got a very remote, small remote community who have for generations suffered from rural depopulation, particularly young people leaving the area and it is happening on quite a quick and more significant scale than ever before. If you are that aging population and you are worried about what you can do to keep those young people in the area and the ability to attract more. An offer of a hundred, two hundred thousand pound a year to the community fund seems like a lot of money and could maybe really turn things around. (12)

These community funds can be utilized in various ways to support communities. However, these community funds can also be viewed as a form of 'bribe' in order to gain community support for resource developments (Geels et al. 2015). Renewable energy development does not only create community funds there are many other aspects to these developments and implications for communities as described by an interviewee from a Scottish local authority,

> So we are in an environment where we are putting huge investment into power [electricity] and it is great it is coming to this part of the world [rural Scotland], it is coming to many parts of the world but we've got lots of construction going on, that's jobs, refurbishment of grid lines, we are having a lot of our youngsters getting into this as their industry. (11)

This quote outlines some of the other positive implications of renewable energy development for rural areas.

Renewable energy development is seen by community members as one of the ways for rural communities to become self-sufficient in terms of generating their own energy as well as a way to generate income for the community. At the same time with the development of renewable energy in the periphery there are large investments being made to build these schemes and the infrastructure to transport this energy from locations of production to locations of consumption (primarily peripheries to cores). These developments affect the core-periphery dynamics. The renewable energy transition with respect to the electricity system is transforming this system as the direction of electricity flow is changing from cores to peripheries, to the reverse, peripheries to cores. The shape of the electricity system is also changing as these new locations of electricity production are developed and the infrastructure such as the National Grid infrastructure is developed to support it. This creates uneven multi-scalar dynamics as this transition occurs within cores and peripheries.

10.5. Conclusion

This chapter presents the analysis of this study. It begins by presenting an analysis of the case study sites in relation to the analytical framework presented in Chapter 4 Towards an Analytical Framework. This chapter also addresses three of the research questions presented in this study around transition dynamics, core-periphery dynamics, and transition-periphery dynamics. The chapter reveals that particular transition dynamics, including the role of policies, targets and legislation, combined with the shift to community-ownership, are creating new dynamics with regards to the energy transition in rural Scotland. The relationship dynamics between cores and peripheries are created through processes of peripheralization that are identified in this chapter to include relational, multi-dimensional processes, and multi-scalar aspects. This research indicates that core-periphery and transition dynamics are an effective analytical tool for understanding these transitions because uneven multi-scalar dynamics are created as the transitions occurs within cores and peripheries. The following chapter presents the discussion of this study by expanding and discussing the implications of the results presented in this chapter.

Chapter 11.

Discussion

This chapter presents the discussion based on the results examined in the previous chapter. This discussion is structured in a similar way to the previous chapter (Chapter 10 Analysis) around three main themes: transition dynamics, core-periphery dynamics, and transition-periphery dynamics. The transition dynamics section examines the political qualities of technology as understood by Winner (1995) with there being two types (as discussed in Chapter 2 Sociotechnical Transitions): inherently political technologies and technical arrangements as forms of order. Inherently political technologies are technologies that are strongly compatible with specific regime structures, systems, infrastructures, and scales. Technical arrangements as forms of order are technologies that are flexible in that there are multiple ways in which they can be adopted. The transition dynamics section also employs the concepts of path dependency and lock-in to discuss the study's results (discussed previously in 2.1.4.3 Path Dependency and Lock-in). The core-periphery dynamics section is structured around and utilizes the concepts of resource making and green grabbing (concepts examined in more detail in Chapter 3 Resource Peripheries). The transition-periphery dynamics section discusses resource development, the role of infrastructure, and the future in terms of where the renewable energy transition is moving towards.

11.1. Transition Dynamics

Sociotechnical transitions involve a range of transition dynamics. This section examines some of these dynamics by discussing the political qualities of technology, as understood by Winner (1995), and utilizing the concepts of path dependency and lock-in to discuss the study's results. These concepts are explored in more depth in the literature review chapter, Chapter 2 Sociotechnical Transitions. The application of these concepts allows for the study's results to be examined more closely and understood in different ways.

11.1.1. Technology's Political Qualities

Sociotechnical transitions are in part shaped by the characteristics of a radical innovation. Niches can have different possible pathways by which they can be adopted into the regime during a sociotechnical transition. This is impacted by the type of technology being adopted because all technologies have political qualities. Winner (1995) identifies two types of technological political qualities: technologies that are inherently political and arrangements of technological order. Inherently political technologies are technologies that are not flexible in that their properties make them particularly compatible with specific regime structures, systems, infrastructures, and scales.

Inherently political technologies

Inherently political technologies are relatively inflexible in the ways they can be adopted which means when adopting these technologies there are specific forms of order that must also be adopted in terms of regime structures, systems, infrastructures, and scales. Nuclear power is an example of a technology that is strongly compatible with Large Technical Systems (LTS) (2.1.4 Innovation Studies) in that they require large-scale, infrastructure intensive systems and regime structures often with a military component involved (Markard & Truffer 2006). Nuclear power requires a strong central government (e.g. UK Government). The flexibility of nuclear power in terms of regime structures, systems, infrastructures, and scales is limited compared to other technologies. Nuclear power is reliant on interdependent subsystems that require a strong central government such as: uranium purification, reactor operation, safety legislation, and waste handling including storage.

Pumped hydro storage is also an inherently political technology because it is strongly compatible as a large-scale development to support a certain type of system with specific infrastructure and regime structures. Pumped hydro storage is the only current proven technology for large-scale storage of electricity (Scottish Renewables 2015a). It tends to be utilized as transmission network scale storage because pumped hydro storage is able to support large electricity systems. Current pumped hydro schemes support daily variations of electricity demand but there is a move towards longer term storage as more renewable energy is developed in the UK. The electricity system in the UK has changed over time with the privatization of the system in the 1990s. This system change has shaped which technologies are adopted and how. This has a political dimension in that pumped hydro storage tends to empower and support further renewable energy development that produces weather dependent (not including tidal or geothermal) and meet short-term fluctuations in demand. Although in the past it supported nuclear power (baseload) in meeting fluctuating demand. With pumped hydro storage in the UK, there has been no new facilities built since before privatization of the electricity system, as described by a manager within a power company in Scotland,

> The pumped storage projects that are operational at the moment, Foyers, Cruachan, Dinorwig, and Ffestiniog, they were all built with government money, by the centralized energy back in the 60s, 70s, and 80s. So they were part of a strategic decision by government to build capacity and redundancy and flexibility into the system. We now have this deregulated system where private enterprise is building generation capacity and government has to incentivize different technologies by providing support to those. Pumped storage hasn't featured in that ever. (14)

Pumped hydro storage requires a certain regime structure and in the current privatised system that means it requires economic profitability through profits from consuming and producing electricity with the daily varying price and demand of electricity. This need for a specific type of regime structure with a market economy is noted by an interviewee, a Scottish Government official,

> To allow pumped storage and any other storage technologies to flourish, we will need the right market and regulatory framework. A framework that recognises the true, long-term value to the system of storage and other flexible, smart technologies. (21)

The regime structure shapes the setup and form of technologies that are adopted. For pumped hydro storage and hydro developments, they are relatively expensive to build and there are insufficient incentives currently within the private system for new pumped hydro storage schemes to be built. The pumped hydro industry is lobbying for increased policy support and regulatory framework changes through long-term assurances and subsidies for pumped hydro storage to make these types of projects financially viable.

The proposed Coire Glas hydro scheme is an example of a large pumped storage development that has received planning approval but is waiting for a final investment decision because of the regulatory framework and policy which Scottish and Southern Energy (SSE) currently views as a barrier. The call for changes to the regulatory framework and market was described by an interviewee, a manager within a power company in Scotland,

> There is a perception mainly in government that these utility companies are in it for the long-term, they'll develop pumped hydro anyway. But actually the hydro schemes were built in the 1930s and were built with government money, foresight, investment, it was all about improving the resilience of energy systems in the country. Because we have a deregulated energy system with private companies, we are not in the business of taking that risk. We are a big utility but we have shareholders to satisfy, so we aren't going to build something that is going to take forty years to pay off because actually we could use that same money to build something that could pay off in twenty years and that is what it is all about, it is about opportunities and where you put your capital. (14)

It is uncertain whether the regulatory framework and policy changes will be made that will support the development of the Coire Glas Scheme and also the proposed expansion of Cruachan. The development of these schemes supports a specific vision for the electricity system that requires large-scale electricity storage as part of a large system.

Technological arrangements as forms of order

Some technologies are flexible and are able to be adopted in a range of ways and can be understood as arrangements of technology as forms of order. The political qualities of a technology and its characteristics restrict the potential technological arrangements. Renewable energy technologies can be understood as relatively flexible technologies that can be adopted in a range of ways in terms of regime structures, systems, infrastructures, and scales. Although a technology may be relatively flexible in terms of its political qualities, it can still be restricted in its adoption by the current system and its infrastructure which can act as a lock-in mechanism and create path dependency (Turnheim & Geels 2012; Unruh 2000). For example with the proposed Shetland Interconnector, it would be a piece of infrastructure that would create the opportunity for renewable energy (or other forms of energy) to be developed on a large-scale for direct export from Shetland. Without the interconnector renewable energy can still be developed, however it is shaped by the infrastructure to support it. This is described by a member of a Scottish Government agency on Shetland,

> Until the Shetland-Scottish mainland interconnector happens we are kind of stuck to these very small community projects… it is just for our own domestic consumption. (06)

Other islands in Scotland are developing their renewable energy in different ways. For example with active grid management and creating increased demand for local electricity is occurring on Orkney as described by an interviewee involved in the renewable energy industry in Scotland,

> We've got Orkney's deployment of electric vehicles to try and use up their excess electricity… We are seeing some of our grid operators run really interesting projects as well to actively manage the grid a bit better and do that sort of smart grid system. (17)

Some technologies can make other technologies more flexible. For example communication technology can allow renewable energy technology to become more flexibly utilized in the system by allowing for renewable energy to be more dispersed and connected to the current National Grid system but remain centrally controlled. As described by an interviewee involved in the tidal industry in Scotland,

> For distributed things we now have the means for communicating with them in pretty much real time which you wouldn't have had 20 years ago. They are so cheap and easy to implement. We can control this turbine from anywhere; you can look at what the grid is doing. What they have been doing in Orkney is distributed management ... It allows local communities to use the resources they have in terms of natural resources while not being wasteful in transmission and other costs. (10)

This distributed management system enables a particular political environment with central control but also the dispersal of the electricity production. In contrast to creating a more dispersed system, renewable energy could be used to create 'energy hubs' in that various renewable technologies could be used in the same location to create more central hubs of production. This concept was described by an interviewee a part of a Scottish Government agency,

> We could cover the ground under these turbines with solar arrays if the habitat is appropriate. Make them much more energy hubs rather than just the ad hoc… There seems to be some appetite for that in Scottish Government. A much more strategic, long-term thinking about sourcing our energy from proper energy hubs rather than this scatter gun approach, which the grid really struggles with at the moment. (16)

This illustrates how the same renewable energy technology can be utilized in different ways such as with 'energy hubs' or a more dispersed energy production system.

11.1.2. Path Dependency and Lock-In

Path dependency and lock-in are dynamics of sociotechnical transitions and can act as inhibitors to transitions. The electricity supply system tends to have strong path dependencies and lock-in because it is a Large Technical System (LTS) with many interrelated components with technical norms and institutions regulating the system (Markard & Truffer 2006, p.609). Path dependency occurs due to lock-in mechanisms that are mutually reinforcing and intricate such as: investments, infrastructure, technical knowledge base, core beliefs, vested interests, behavioural patterns, subsidies, and regulations (Turnheim & Geels 2012; Unruh 2000). The electricity supply system in the UK involves institutions like Ofgem (government regulator for gas and electricity markets) and legislation that create certain path dependencies and lock-in. These path dependencies are also reinforced by significant investments and infrastructure including transmission and distribution lines built to support a specific type of arrangement of energy production. This infrastructure is aging as described by a member of a local authority in the Highlands of Scotland,

> The grid network in the late 1960s and 1970s had been grown on the back of coal, oil, gas, nuclear, and as we've aged through the end of the last century, these power plants are getting old, they're getting tired. (11)

The development of renewable energy in the resource peripheries of Scotland has led to this electricity transmission and distribution infrastructure being utilized in different ways as electricity is being produced throughout the periphery. A resident of Shetland involved in the renewable energy industry described the change in flow of electricity to from the periphery,

> The grid was not designed to take power from the remote parts to the cities, usually power stations are central and they pump power out to the periphery so you've got to build a whole new network to carry high voltage power from distant places to where it is needed which is the cities. (05)

The electricity system is being challenged in new ways as the geography of electricity production is changing as shifts in energy production sources and technology change over time. Reinvestment in the system is needed to support this change in electricity flow as a member of a local authority in the Highlands of Scotland describes,

> We are having to completely reinvest in our grid network, so we had the Beauly Denny line for example, but all the other networks across the Highlands need to be modernized. They've been standing for fifty to sixty years, they need refurbishing but they also need upgrading in order to carry the capacity. What you've got to realize is this part of the world the history of the grid network grew from the cities, Glasgow, Edinburgh, and came up the east coast and only came to the Highlands in the 1950s. This is sixty years on, and what we're finding is you've got a system that is distributing power to the north but sixty years on we're generating lots of power in the north and we're now trying to distribute it to the south so it was turning the technology on its head. You can reverse that but you need much more in terms of substations and transformers. (11)

The electricity system infrastructure is aging in Scotland and projects, such as the Beauly Denny power line upgrade, are occurring to support the transitioning electricity system. The Beauly Denny power line upgrade was completed in 2015 and involved a 600-pylon network of 220km (137mi) to increase capacity to transfer renewable power from the Highlands to central Scotland. The role of the Beauly Denny project was described by an interviewee from a utility company in the UK,

> Beauly Denny was built to reinforce the spinal backbone of the transmission system right down to the city centres of Scotland. It has been driven by renewables, there's been a large volume of wind farms in the northern and north eastern corners producing energy into the system and that infrastructure needs to be in place to take it and transport it down to ultimately the load centres which for Scotland is predominantly Aberdeen, Edinburgh, and Glasgow and the central belt, and more importantly most of that energy is actually probably flowing out of Scotland. (08)

The Beauly Denny power line upgrade is only one example of where the infrastructure investments are being made with the purpose of supporting the development of electricity production through flexible technologies in the peripheries of Scotland. Other projects such as interconnectors that are proposed to connect Shetland (second case of this study) and to the Scottish Western Isles are also being proposed or built to support the production of electricity in peripheries. However, previously these interconnectors were built to supply electricity to these peripheries, rather than from them.

There is reinvestment in the electricity grid occurring throughout the UK. However, the electricity grid is still considered a ‘constraint’ to renewable energy development in many locations as described by an interviewee involved in the renewable energy industry in Scotland,

> You can have these targets, ambitions, these bits of legislation which do an awful lot, and I wouldn’t want to belittle the role they play but there are then sometimes very practical pressures on developing this industry. A big one in Scotland is grid. The fact that this network is so constrained. And the chicken and egg situation that arises of grid not able to commit to these infrastructure costs, developers not being able to commit to sites until that infrastructure is in place, this chicken and egg system. And obviously it is a heavily regulated arena, Ofgem are in very much command and control. (17)

This quote shows the role infrastructure plays in renewable energy development in relation to other influences such as legislation, subsidies, and institutions like Ofgem which can also create path dependencies and lock-in. Each of these aspects have a role in shaping how and if a sociotechnical transition can occur, and the geography of that transition.

11.2. Core-Periphery Dynamics

There is a range of core-periphery dynamics in relation to renewable energy development in Scotland. There is a variety of processes during a sociotechnical transition that create core-periphery dynamics in relation to these resources that are geographically uneven. Some of these processes can be understood as resource making and green grabbing. These terms resource making and green grabbing are described in more depth in Chapter 3 Resource Peripheries.

11.2.1. Resource Making

Resource making is an integral part of the creation of resource peripheries and the potential development of core-periphery dynamics. Renewable energy development has involved resource making. Resource making is a process by a person or society to impose new values that create commodification and enclosure. These are processes that occur over time through people's wants and actions (Zimmermann 1951). Resource making is inherently a geographically uneven process (Bridge 2010). This uneven development from the enclosure and commodification of resources is noted as reproducing the classic core-periphery dynamics by Bridge (2010).

Scotland can be understood as a periphery with a range of resources and its relatively low population density compared to other parts of the UK and Europe. Many factors shape the way in which resources are made and can influence development. Resources are shaped by the ability and desire to harness and transform them into a product. For example, the desire and ability to capture wave energy and convert it into electricity. This is a technological challenge that is in the research and development stages of development. Efforts are being made to develop this wave technology however it has struggled as described by a member of a Scottish Government agency,

> What's been the problem in the past two or three years has been effectively the people who were building scale devices before they were solving the technology problems, and that was in retrospect a reflection of the start-up venture funding that was supporting these companies, effectively what was trying to be done was, using a media or IP tech start up, quick, short, investment to get to a commercial project when effectively you were looking at something more akin to taking on the aerospace industry or life sciences industry which requires a sustained long-term R&D and significant amounts of testing before you can go near the water. In retrospect the utilities came in too soon, they were promised working machines… they came in and invested in these companies actually before they were ready to be invested in. (09)

There are economic elements as the technology needs to be economically viable with market opportunity in the current privatized electricity market for wider commercial-scale adoption after research and development.

There are also social and geographical implications if a technology is adopted. This market opportunity was described to be created through policy in the electricity sector,

> In the electricity market it is effectively policy drivers that create the market opportunity. Now the wave and tidal sector is a tiny little part of that but I think if you ask industry and utilities it is clear that government ambition and aspirations in the sector give confidence for going forward. (09)

Although policies create opportunities within the electricity market for certain resources to be developed, there are also local scale factors that create uneven development. For example, a member of a Scottish Government agency on Shetland described how the renewable energy resource development was being shaped by local factors on Shetland,

> We have to flex the policies [public policies] for local conditions and at the moment we don't see a lot of renewable energy because there's no avenue or outlet to develop it at the moment, there is no way of exporting it. (06)

There is local policy support for renewable energy development on Shetland such as in Highlands and Islands Enterprise (HIE) policy (Highlands and Islands Enterprise 2016). However there are 'limits' to its development in part because the current system is not organized to export or consume the potential excess from current electricity demand as described above. These 'local conditions' create uneven resource development which in turn can lead to the development of cores and peripheries. As technologies for renewable energy generation for wave and tidal move into mainstream commercial markets there is likely to be further commodification and enclosure of the relevant parts of nature.

Economies based on primarily resource development have been linked to short-term economic growth and 'boom and bust' cycles of development, also known as the resource curse (Barbier 2015). This type of resource development has been a characteristic of Shetland. Shetland has experienced many 'booms and busts' of resource development. Shetland's current main industries are aquaculture and oil and gas. An interviewee involved in a community development organization on Shetland described the aquaculture industry,

> We [North Yell] process an awful lot of farmed salmon, there are millions of pounds worth of salmon that get shipped through the harbour and we've got farmed shell fish as well. There is a processing plant facility down at the harbour and it's selling all over the world, mostly to the UK but often to Japan and places like that so we do very well… Although the community is getting on slowly now with our local school under threat of closure for many many years. We need to be tackling, well continuing to tackle that all the time to make sure we try and keep off the closure list. (01)

This quote illustrates that although there is a large aquaculture industry involving large exports on Shetland there are still difficulties such as around keeping one of the local schools located in one of the smaller islands open. In order to lessen the negative impacts of these cyclical resource economies the Shetland Charitable Trust was created in 1976 to receive and distribute funds from the oil and gas development on Shetland (the Trust is described in more depth in Chapter 8 Shetland Interconnector). However, the oil and gas sector is currently in a certain amount of decline as reflected by the decreasing Shetland Charitable Trust annual budget from £15 million in 2003 to £9.8 million in 2015/16 (Riddell 2015; Marter 2011). The Shetland Charitable Trust is looking for other avenues to generate funds to compensate for the decreasing oil and gas contributions. This situation was described by a resident of Shetland involved in the renewable energy industry,

> Shetland community has experience working with the oil industry, we earned a lot of money from hosting the Northern North Sea Oil Industry. Since then the amount of money we earn from the oil industry for community funds has dwindled a lot and we've been looking for something else, for a new golden goose that could lay a few golden eggs. (05)

The proposed Shetland Interconnector, case two of this study, is perceived by some as the 'new golden goose' solution for Shetland. However, this is not the only 'solution' since there are many different potential forms of development that could occur.

Renewable energy development is one of the current forms of resource development that communities can be involved in to generate income. For communities in the periphery renewable energy development is perceived as one of the few forms of development for them to take part in as described by a member of a Scottish Government agency,

> For communities it's a way they can earn money. Some of these peripheral areas don't have many ways they can earn money and tourism is one but renewables is a really good one for some of them and perhaps for some of them it is probably the only thing they could do. (07)

Although renewable energy development can be a large income generator for communities, these developments are reliant on policies and subsidies that create the market opportunities for these types of developments to be viable. This makes them vulnerable to policy changes such as with the recent changes to subsidies with certain subsidies being closed early such as the Renewables Obligation (RO) and Renewables Obligation (Scotland) (ROS) for large-scale solar PV (closed April 2015) and new onshore wind power projects (closed April 2016 which is one year earlier than originally planned). This leads to the question of whether renewable energy development will create long-term sustainable development or contribute to peripheries experiencing boom and bust cycles of resource development.

11.2.2. Green Grabbing

The making of new resources with respect to renewable energy and its development has led to forms of green grabbing in the peripheries of Scotland. More specifically, the green agenda for more renewably sourced electricity has involved imposing certain values and needs on the peripheries. Green grabbing refers to land and resource 'appropriation' for 'environmental ends' and justifications as described by Fairhead et al. (2012, p.238). Green grabbing has come about through new forms of commodification, valuation, and markets (Fairhead et al. 2012). This green grabbing can be through the green agenda which Fairhead et al. (2012) has identified as a new form of legitimization used to justify land and resource appropriation. The development of renewable technology and the incentives such as in the forms of subsidies have created relatively new values on parts of the environment such as for wind, tidal, and wave. These resources tend to be located in the periphery and the people who live in these areas are vulnerable to their lands being 'appropriated' through green grabbing. I suggest that green grabbing and other forms of resource grabs are part of the peripheralization processes that reinforce the core-periphery power-dynamics.

Some of the local people are concerned that Shetland's wind resource will be in a sense 'funnelled' away with little to no consideration for the local people of Shetland. This is described by a member of an active community organization on Shetland,

> What is their [government] vision for this place? Do they [government] just regard it as a super wind funnel to suck wind out of without any regard to the people? (04)

This quote illustrates the concerns of locals over the visions and influences of government and the impacts on local people. Resource development impacts the local people in a range of ways. The green agenda is a form of legitimization to justify land and resource appropriation (Fairhead et al. 2012). These types of justifications are being used on Shetland in relation to renewable energy development as stated by a resident of Shetland involved in the renewable energy industry,

> Shetland is not going to avoid playing its part in the renewables revolution and trying to tackle climate change, not with the resources it's got, the wind and wave and tidal, it would be ludicrous and selfish of Shetland not to try and do something to tackle climate change when we are going to be affected by it as well… We've gained so much from the burning of fossil fuels, and then surely it is morally required to give something back by using its renewable resource. (05)

These types of justifications and moral arguments have a tendency to put the green agenda ahead of the concerns for the livelihoods of the rural people. The green agenda is expressed in various ways such as through the national and international targets for Greenhouse Gas (GHG) emissions and renewable energy development.

Population density is an aspect often used to justify locating certain resource extraction in resource peripheries where population density is low. Scotland is a relatively less populated area compared to other parts of the UK and Europe with a range of resources. One interviewee who is an analyst for an European Union (EU) lobby organization described Scotland's wind resource in relation to its population,

> Scotland is a very interesting country basically because it is very very windy. It is not extremely densely populated which means it is possible to build quite a lot of wind power. I guess that is clear in contrast to England when it comes to the United Kingdom. (20)

This lower population density leads to justifications and arguments for development of resources in these areas because it will directly impact a fewer number of people.

People who live in the periphery are vulnerable to their lands and resources being 'appropriated' through green grabbing. This sense of vulnerability was noted in the previous chapter (Chapter 10 Analysis) in relation to 'influences we have no control over' as stated by an interviewee a part of a community organization in Shetland which is a peripheral region in Scotland (as noted in Chapter 7 North Yell Tidal Scheme). They (01) also described the issue of government funding and vulnerability in a quote in section 10.4.2 Niches and Renewable Energy Development. This sense of vulnerability may be increasing as local economies become more interlinked with national and international economies. Green grabbing involves the imposing of certain values and needs on others, such as the green agenda for more renewably sourced electricity on rural people. The increased interlinking of economies is described by Zimmerman (1951), "village and town economies have merged into national economies and these, in turn, have become subject to world economic influences" (p.28). I suggest that this interlinking of economies could be increasing the influences on peripheries which contribute to more complex core-periphery dynamics and green grabbing.

11.3. Transition-Periphery Dynamics

There are complex transition dynamics as well as core-periphery dynamics during a sociotechnical transition as discussed in the previous two sections of this chapter. There are also dynamics that can be understood as transition-periphery dynamics. The capacities of different locations and other factors such as policies affect the uptake of new technologies or radical innovations during a transition causing spatial differentiation. With the low carbon energy transition there will be a re-working of the established core and periphery patterns at different scales creating new patterns of spatial differentiation (Bridge et al. 2013). There will also be new forms of transition-periphery dynamics.

This section of the chapter discusses some of the transition-periphery dynamics found in this study and presented in the previous chapter, Chapter 10 Analysis. This section begins by discussing resource development and the different forms renewable energy can be developed with different transition-periphery dynamics. This is followed by the role of infrastructure particularly focusing on interconnectors such as the proposed Shetland Interconnector and interconnectors more generally in the UK. Then the future of renewable energy development is described with discussion around different sources of electricity generation and how the system may develop into the future.

11.3.1. Resource Development

Resources can be developed in a range of ways. The way in which peripheral resources are developed and organized can be centralized over time. For example with respect to aquaculture on Shetland a local resident involved in the renewable energy industry described the centralization of ownership and resource development in aquaculture,

> All the salmon farms are owned by Norwegians now. It started off small, the idea was that a crofter would have his sheep and a wee cage full of fish to feed the sheep, feed the fish, make a bit of money, diversify but then salmon farming went the way it did, consolidated, every few years it consolidates further so there's only about three companies that own all the salmon farms on Shetland a part from one or two, one on Unst and one on Yell. It's a multimillion pound business. Sometimes you've got to play at that level otherwise you're not in the game. (05)

This quote illustrates how these places have developed over time with processes of centralization through consolidation. The way in which the renewable energy on Shetland is being developed could take a similar path in terms of consolidation. The Viking Windfarm proposal is in some sense a way of developing the wind energy on Shetland in a centralized way with the interconnector to the mainland as the export link. In contrast, a decentralized development of the wind energy could occur through alternatives such as smaller scale developments with more diverse ways of storing and exporting the electricity. However, it is possible to have a centralized development and consolidation of renewable energy with alternative forms of storage. There are different forms of renewable energy occurring on some of the Shetland Isles including Fetlar and Foula.

An example of a different approach to renewable energy development in Shetland is on the isle of Fetlar (described previously in 8.3.3 Fetlar). Fetlar is one of the North Isles of Shetland with a population of roughly 86 in 2001 (Shetland Islands Council 2011) and 70 people in 2015 (02). There is a renewable energy project on Fetlar that involves two wind turbines of 25kW and two thermal water stores with private wire to supply electricity to several buildings and an electric minibus. The project was shaped by the feasibility of upgrading the interconnector from the Isle of Yell to Fetlar under the current regime conditions,

> Ideally we'd like to put up a single big turbine. We had a couple of prospective sites for that but the issue is that our cable between Fetlar and Yell couldn't support the export potential of that turbine. To upgrade the undersea cable would be crazy money. Either you have to put up another half dozen turbines to just provide the cost of the cable. That's really not what I was looking to do. We would have been an exporter at that time because what I was looking for was income generation. Tick the box, I put this up, it makes £250,000 a year. But that wasn't an option… We are hoping that at some point we will be able to get an export but ideally we would like to use as much of the power or all the power locally. (02)

The infrastructure aspect of the interconnector and the potential to upgrade this infrastructure shaped the renewable energy project from an energy export project to an energy project for primarily local use. The project encountered difficulties financially as the subsidy regime changed over time during the planning stages of the project,

> We originally started the project 5 years ago. Since we started the value of the Feed-in-Tariff has halved. So it has had a huge impact on the income from the project. The rules have changed about how we can fund the turbine. (02)

This challenge of a quickly changing policy environment in the UK being a challenge to community energy more widely is noted by Smith et al. (2016), community energy "groups have had to be very nimble, entrepreneurial, and resilient in seizing opportunities amidst a shifting policy landscape" (p.416). Fetlar's renewable energy development exemplifies one form of development with a flexible technology (in terms of technological arrangements as forms of order) as a way for a peripheral community to decrease some of the negative aspects of being a periphery.

The different types of energy development have different impacts on peripheral communities. Renewable energy sources such as wind, solar, and tidal are a more dispersed resource compared to other more conventional energy resources (e.g. fossil fuels) and therefore their impacts on local areas can be more dispersed. Development of certain forms of renewable energy has been described to bring people 'closer to energy production' as described by a member of a Scottish Government agency,

> The wind development across Scotland, the extent and speed of which it has arrived, I suppose like the grid in the 1950s and 1960s ... across the Highlands ... it probably has brought people closer to energy production than anything else apart from some of the nuclear scares and maybe the coal mine strikes and stuff like that has certainly brought energy to the fore again as a discussion. And all the under bubbling of climate change and subsidies and even the land ownership questions as well. (16)

However, the people that are being brought 'closer to energy production' are those located where these resources are, which is primarily in rural areas, peripheries. As time passes new forms of resource development have a tendency to become more accepted. This also applies to the infrastructure that supports these developments. As the same interviewee further described,

> I am sure it was the same in the 50s and 60s when the grid took off across the Highlands and you had the benefits that that would bring, lighting, improved health care, improved conditions and all that, versus people that had lived on wee glens that hadn't seen any wires or poles or infrastructure and wanted to live in isolation, went through the exact same I am sure. Back then as time goes on you kind of get used to that infrastructure, poles and pylons. Perhaps it will be the same with wind. (16)

For some of these regions with a history of resource extraction there is a discontentment about the current development of renewable energy in these same locations. These types of developments could be reproducing what Dalglish et al. (2017) describe as 'deeply-embedded historical injustices'. However, renewable energy, as noted by Murphy and Smith (2013), "has the potential to reproduce or transform this setting over the decades ahead in a wide variety of different ways" (p.703). For example as described in Ayrshire by a member of a Scottish Government agency,

> Ayrshire has a lot of coal mining and industry, we've had this on our doorstep for thirty, forty years or more and now you put a wind farm in because it is a brown field site. (16)

These resource peripheries are experiencing the development of renewable energy which is a part of a larger sociotechnical transition to renewable energy.

11.3.2. Interconnector Infrastructure

Interconnectors in the electricity system are important pieces of infrastructure that shape the types of technological arrangements of order made possible by renewable energy development. Interconnectors can connect cores and peripheries directly together in terms of electricity and its extraction as a resource. Interconnectors are part of the electricity system's infrastructure and can shape the types of energy production developments that are possible. They can be used to frame specific types of development such as with large-scale renewable energy developments and exports.

Interconnectors can to some extent lift constraints and enable large-scale development and export of renewable energy. With the case of Shetland, a certain amount of renewable energy has already been developed without an interconnector, 7% of electricity produced is from renewables (Scottish and Southern Energy 2010). This has mainly been wind-generated but there is a large amount of further renewable energy that could be developed. The Shetland Interconnector would drastically alter the constraints on Shetland's electricity grid. Large-scale renewable energy projects such as the Viking Windfarm (370MW) could be built if there was an interconnector along with additional space (188MW) on the interconnector for other renewable energy developments (or non-renewables) to export electricity (Scottish Government 2013). The Shetland Interconnector and the associated Viking Windfarm as it is being presented, "has quite a specific path or vision for Shetland, it seems quite a crossroads" (05) as described by a resident of Shetland involved in the renewable energy industry. The situation on Shetland with its 'constrained' grid is not specific to Shetland as described by a member of a Scottish Government agency,

> The grid on Shetland can only take so much power and until the interconnector gets built... But that's the problem right down the whole west of Scotland, there's no decent grid because it wasn't designed that way, it was originally designed around big power stations close to Glasgow and Edinburgh and the power coming out from that got gradually more peripheral and smaller cables as you get out to the sticks. But of course now you have a big clump of power on one end that you need to put on little bits of string to get down, so that is the dilemma. (07)

As this quote illustrates, the need for new and upgraded infrastructure for the electricity system has been identified as the type and location of electricity production is shifting from large power stations to more peripheral, dispersed forms of electricity production (renewables).

Further renewable energy development on Shetland is restricted by the current infrastructure and local energy demand. Shetland's electricity demand ranges from roughly 11MW up to 48MW at peak times (Shetland Islands Council 2009a; Northern Isles New Energy Solutions 2015). The current proposed Shetland Interconnector would have a capacity of 600MW and cost an estimated £600 million (Bevington 2014). This 600MW capacity would leave a large amount of space for other renewable energy to export since the proposed Viking Windfarm is 370MW. The interconnector would also mean that renewable energy schemes such as the proposed Garth Wind Farm that has a constrained grid connection permission of 30%, could have this constraint lifted which could increase North Yell Development Council's (NYDC) output and income by 30% (outlined in 8.3.2 Garth Windfarm). However, the cost is high to construct the interconnector and it is not clear yet whether it will go ahead at this time. There are also other constraints on renewable energy development such as suitability of areas for development due to various environmental sensitivities that exist throughout Shetland.

A practical issue for infrastructure is often who should bear the costs of this new and upgraded infrastructure such as producers, consumers, or government. This is the case with interconnectors such as the proposed Shetland Interconnector. This situation was described for the case of the Western Isles by an interviewee from a utility company in the UK,

> There is an option to take a cable to the western isles, but at the moment the commercial business case for that is not justified because the wind farm developers have got to demonstrate that they are ready to build a wind farm and committed to build a wind farm before we will build infrastructure so we don't build it in advance of a contractual position. We build it once a contractual position has been secured and there's a need for it to be built, we only do as a requirement. The down side of that is sometimes there are long delays between what people need and what they actually gain but equally we aren't wasting money building large-scale infrastructure on a speculative bases when the wind farm generation requirement isn't there. I guess it is one of those chicken and egg situations, which one do you actually need to have first to close the loop off. But for a regulative point of view we will only build when there is a commercial driver to do so, so we won't do it speculatively because we don't get paid from Ofgem or the customer. (08)

This 'chicken and egg' situation between interconnector infrastructure and renewable energy developments is created because of the way the system operates. Electricity producers would pay a 'use of system charge' for transmission through the interconnector, such as the Viking Windfarm for the Shetland Interconnector (North Atlantic Energy Network 2016, p.12). However, the Viking Windfarm cannot be developed without the interconnector because the Contract for Difference (CfD) contract would require the Viking Windfarm to become operational in line with the Shetland Interconnector completion dates. At the same time the interconnector must have a needs case that outlines the technical and economic justifications for Ofgem. In a sense, one scheme cannot be built without the other but they rely on different support mechanisms (subsidies such as Contracts for Difference (CfD) and investments). Cost escalations and needs cases have also been identified by the Scottish Government (2013) as reasons behind delayed interconnector projects for some of the Scottish islands.

The Scottish Islands have been identified as having a large renewable energy resource. As described by the Scottish Government (2013),[88] "the Scottish Islands offer

[88] DECC and the Scottish Government commissioned an independent study, the Scottish Islands Renewable Project (2013), "to assess whether Scottish Island Renewables could make a cost effective contribution to meeting the UK's renewable energy targets and to determine whether any additional measures are required to bring these projects forward" (p.5). The report found that the Scottish islands could make "a significant contribution to Scotland's and the UK's 2020 renewables targets, as well as playing an important role in longer term decarbonisation objectives" (Scottish Government 2013, p.5).

some of the best sites for renewable projects anywhere in the UK, and indeed Europe, due to the high winds, waves and tidal flows" (p.6). However, the development of renewable energy on these islands tends to be framed in a specific way as shown with the Shetland Interconnector case. The framing of how smaller renewable energy projects are reliant on larger renewable energy projects to justify interconnectors in the Scottish islands is seen in the Scottish Islands Renewable Project (2013) Final Report,

> For some developers, particularly for smaller or community owned projects or those with new technologies, the grid access challenge is even greater since they are unable to underwrite the liabilities and associated security requirements needed to secure capacity on future transmission links. As a result these developers are dependent on 'anchor projects', such as large wind farms in the Western Isles or Shetland or large marine projects in Orkney, to underwrite new transmission investment, and hope that there is sufficient spare transmission capacity to accommodate their projects. (Scottish Government 2013, p.7)

The Scottish Islands Renewable Project (2013) Final Report found that the current policies were not supportive of renewable energy development for the Scottish islands. The interconnectors are viewed in this report as being central to the Scottish Islands being able to contribute to the UK and Scotland's 2020 renewable energy targets,

> Further renewable generation on the Scottish Islands will not be developed on any scale in the near term under current policy. The costs of connecting to the transmission system are too high, making it difficult for developers and the regulator action on behalf of customers to commit to costly new transmission infrastructure. In turn, the lack of grid access deters new developers, particularly those not in a position to meet the financial commitments required to secure future grid capacity. Ongoing uncertainty will inevitably lead to delays meaning that, despite the potential, renewable generation on the Scottish Islands would only make a minimal contribution to 2020 renewables targets, and an opportunity to develop the UK as a world leader in marine renewable could be lost. (Scottish Government 2013, p.8)

The development of renewable energy on the Scottish islands is viewed as being beneficial for these peripheries as well as part of contributing to reaching renewable energy targets.

Interconnectors can be utilized in various forms to develop renewable energy. An example of a different approach to renewable energy and interconnector development as compared to Shetland is that of the Orkney Islands. There is large renewable energy potential on Orkney and it is grid connected to the UK mainland. The Orkney Islands have already developed 66.7MW of renewable electricity although the local demand ranges between 8.7MW and 33MW (Scottish Government 2013). The Orkney Islands are somewhat different from Shetland with respect to renewable energy development because their grid system has five or six ‘pinch points’ within the network. These ‘pinch points’ are where there is too much electricity on a specific section of the grid than what the grid is designed for, and this is balanced by a generator being turned off (Kreith & West 1996). One interviewee described how much more developed Orkney’s renewable energy is compared to Shetland,

> Shetland is already years behind the Orkney Islands. Orkney has got grid connection to the Scottish mainland, not a very big one but it is more or less self-sustainable in its renewable power, not that renewables provide all the power it needs, it’s got 600 renewable connections already and Shetlands got very few. Shetland’s been held back by the lack of connection [to the UK mainland] and the attempt to get the connection has been held back by the court process, by the challenge from Sustainable Shetland. (05)

The development of renewable energy on Orkney and its UK mainland interconnection exemplifies a form of development that Shetland could potentially follow. However, Shetland is located much further from the UK mainland than Orkney which means the costs to construct an interconnector is likely much higher along with higher losses in electricity through the increased distance in transmission.

11.3.3. Future

The current electricity system in the UK is in transition as aging infrastructure such as the grid and power plants are being decommissioned and upgraded. The organisation of the system is also changing in terms of its current centralized nature with large energy production centres to a more dispersed system of electricity generation. As renewable energy is further developed in Scotland to meet the GHG emission targets and renewable energy development targets, this development could take different forms. There is also the question over how the aging renewable energy developments such as wind farms that are coming to the end of their life spans are going to be repowered or decommissioned.

The UK's electricity generation sector has been characterized largely by a number of centralized large-scale thermal power stations that are linked to the national transmission grid (Nelson 2013). Scotland's electricity generation system has decarbonised with the closure in 2016 of the last coal-fired power station, Longannet located in Fife (with a capacity of 2.4GW). This marks a large shift in Scotland's electricity system. Nuclear power generation contributes a large portion of the electricity generated in the UK at 20.8% in 2015 (DECC 2016). This is in contrast to Scotland where nuclear generated electricity contributed 35% of generation in 2015 (second to renewable at 42% and fossil fuels at 22%) (Scottish Government 2017a). However for Scotland the Scottish National Party (SNP) have a commitment to not developing any further nuclear power within Scotland. This could change over time as political priorities and parties in power change. There is support for the building of new nuclear power stations in England where the Hinkley Point C Nuclear Power Station (3.2GW)[89] was recently approved (project to begin producing power in 2025). Hinkley Point C will receive subsidy support through the Contracts for Difference (CfD) scheme (House of Commons Scottish Affairs Committee 2016). Nuclear power stations in Scotland such as the Torness and the Hunterston B power stations have had their life spans extended. This shift away from coal-fired electricity generation and nuclear power in the electricity system in Scotland was described by an interviewee from a Scottish Government agency,

> Scotland has a decarbonised electricity generation system with Longannet closing. We've basically got two very large nuclear power plants and a very large amount of wind... we've got a decarbonised electricity system in Scotland. Which means that particularly as the nuclear power comes off as the 2020s move through we are going to be a country that is exporting energy when it is windy and wet and one that will have to import energy when it is not windy or wet. One that will probably be looking at a more locally-based system. I think the days of the 1950s, 1960s, 1970s central generation, distributing to the peripheries is changed a whole paradigm has

[89] 3.2GW is equivalent to roughly 7% of Britain's electricity demand (UK Government 2016).

> changed and we are looking at much more locally focused systems that crucially involve heat and transport at the same time. (22)

Although a more locally-based electricity system is possible there is also discussion around the creation of ‘energy hubs’ with respect to future renewable energy development. Pumped hydro storage could also support further wind energy development while decreasing the need to rely on imports of electricity.

Past history such as through path dependency and momentum through lock-in continue to be important and influence sociotechnical transitions. As the UK’s electricity system is part way through a sociotechnical transition towards renewable energy production there are many different possible forms the new system could take which all have core-periphery implications. This is in part being shaped by the existing infrastructure including the National Grid as described by an official from a Scottish Government agency,

> That’s the problem right down the whole west of Scotland, there’s no decent grid because it wasn’t designed that way, it was originally designed around big power stations close to Glasgow and Edinburgh and the power coming out from that got gradually more peripheral and smaller cables as you get out to the sticks. (07)

For example, there is potential for a move towards ‘energy hubs’ as described by an interviewee (16) a part of a Scottish Government agency earlier in 11.1.1 Technology’s Political Qualities in the subsection about Technological arrangements as forms of order. These energy hubs would include multiple types of energy production in one location, such as wind and solar. This type of setup attempts to centralize electricity production which is more in line with how the current electricity system is organized. There is also potential for smart grids in order to more tightly manage the production and consumption of electricity as described by an interviewee from a Scottish local planning authority,

> Smart grids are really quite intelligent solutions to try and make use of higher amounts of renewable energy within an existing energy infrastructure, maybe with some extra control such as the smart meters, intelligent devices and it is all about how you make this commercially affordable. (02)

Both these examples of energy hubs and smart grids illustrate how infrastructure and other aspects of path dependency shape the sociotechnical transition and options as these new ways of organizing around new forms and locations of electricity production are shaped by the current system.

For wind energy looking forward there is the new aspect of repowering these wind farms that are beginning to reach their 'end of life'. A portion of the currently operating wind farms will reach their end of life (lifespans are roughly 25 to 30 years) before the 2020 target which is when the EU 2020 legally binding targets must be met. An interviewee who is a part of a Scottish Government agency described this repowering of wind farms in Scotland,

> At the moment the developers are leaving it to the eleventh hour if they are going to repower or not and it depends on the subsidies in the market, the energy market etc. A whole number of things might influence it and then they say, nah, we will leave it and they are obliged to decommission the site and walk away. (16)

This 'last minute' decision making about repowering wind farms is difficult for local communities in part for communities that receive community benefits from these wind farms. It also makes it difficult for renewable energy targets because there is uncertainty of the length of time these wind farms will operate in terms of repowering. This has brought into question the long-term planning for these wind farms. As the same interviewee described there are potential changes to attempt to improve this,

> We are also talking about extending the duration of consents as well so maybe more than 25 years, maybe 100 years. Thinking much more cleverly about the layout, design and long-term future proofing of wind farms... it gives the developer that kind of certainty over the long time, all they have to do is buy the new turbines essentially so they can keep producing. (16)

Extending consents for wind farms would allow for longer term planning for sites which could have implications for resource planning, investors, and policies. However, it could also lead to longer term green grabs in that these developments would not be reassessed for planning approval as frequently.

In terms of renewable energy technologies wind power has expanded quickly over the past two decades in the UK. However, newer forms of renewables such as wave and tidal will be and are beginning to develop from the niche stage of development. Forms of renewable energy such as wave and tidal are likely to begin to become large contributors to the electricity system in the UK in the future. Tidal power in particular has already begun to be developed as projects such as the Meygen Project (in the Pentland Firth) and the Shetland Tidal Array (Bluemull Sound) move forward and expand. However, as these newer forms of technologies for renewable energy generation move into mainstream commercial markets there is likely to be further commodification and enclosure of the relevant parts of nature. This will have transition-periphery dynamic implications as has been described in this chapter.

11.4. Conclusion

This chapter presents the discussion of the results of this study around three main themes: transition dynamics, core-periphery dynamics, and transition-periphery dynamics. The discussion showed that sociotechnical transitions involve a range of transition dynamics that are in part created by technologies' political qualities as well as forms of path dependency and lock-in. Inherently political technologies (as noted by Winner (1995)) are relatively inflexible and therefore adopting these technologies mean there are specific forms of order that must also be adopted in terms of regime structures, systems, infrastructures, and scales as described with nuclear power and pumped hydro storage in this chapter. Renewable energy technologies in comparison can be understood as relatively flexible technologies that can be adopted in a range of ways in terms of regime structures, systems, infrastructures, and scales. Although a technology may be relatively flexible in terms of its political qualities, it can still be restricted in its adoption by the current system and its infrastructure which can act as a lock-in mechanism and create path dependency. In terms of core-periphery dynamics this chapter demonstrates how resource making and green grabbing are inherently geographically uneven process. These processes also create core-periphery dynamics in relation to these resources. Cycles of boom and bust resource development are typical development cycles in resource peripheries as described with Shetland in this chapter. Green grabbing through the green agenda is imposing certain values and needs on the periphery as renewable energy is being developed in certain ways as can be seen with the proposed Shetland Interconnector and the Viking Windfarm.

Resource peripheries are experiencing the development of renewable energy which is a part of a larger sociotechnical transition to renewable energy. As a part of this transition, interconnectors and associated renewable energy development proposals tend to be framed in a specific way as shown with the Shetland Interconnector case. This case illustrates how interconnectors tend to be associated with large-scale renewable energy development proposals and with the intention of direct export of electricity. There will be further transition-periphery dynamic implications as the various forms of renewable energy are further developed.

Chapter 12.

Conclusion

This chapter presents the conclusion by discussing the key points of the study and implications of the findings. The chapter begins by outlining the research questions of the study and the answers to these questions. Next the theoretical and policy implications of the findings are described. This discussion of implications includes a number of policy recommendations. This is followed by a discussion of the limitations of the study. Recommendations for further research are then made. The chapter finishes with a brief wider discussion of cases from other parts of the world from that of this study's focus of Scotland where the transition-periphery dynamics appear to be present.

12.1. Research Questions

The study's objective is to understand and uncover insights for theory and policy. More specifically, the study focuses on the core-periphery dynamics of the transition towards renewable energy occurring in Scotland, UK. This objective is addressed through a set of four research questions initially presented in Chapter 1 Introduction. These questions are addressed through a collective case study of three cases: North Yell Tidal Scheme, Shetland Interconnector, and Coire Glas Pumped Hydro Scheme (with proxy Cruachan). The focus of this study is on Scotland. However, in order to include the various influences and systems involved the unit of analysis includes differing levels of jurisdiction including the EU, UK, and Scotland governing authorities as well as the UK market and infrastructure. Data was collected primarily through 22 semi-structured interviews relating to the three cases as well as the landscape and regime levels of the electricity sociotechnical system focusing on Scotland. Interviewees included community members, local authorities, energy suppliers, energy regulators, government departments, government agencies, industry bodies, non-governmental organizations, and transmission network operators. Information was also collected through policy and planning documents available online. The data were analyzed for common themes through identification of key phrases, ideas, and concepts (Krueger & Casey 1994).

12.1.1. Research Question 1: Geographically sensitive model

The first research question of this study is as follows,

1. How can the multilevel perspective (MLP) on sociotechnical transitions be incorporated with the concept of resource periphery to create a more **geographically sensitive model** for understanding new resource peripheries?

In order to answer the first research question an initial literature review was conducted on sociotechnical transitions and resource peripheries. The sociotechnical transitions literature review is presented in Chapter 2 Sociotechnical Transitions and the resource peripheries literature in Chapter 3 Resource Peripheries. This study proposes a theoretical framework that extends and refines the multilevel perspective (MLP) of sociotechnical transitions by incorporating the geographical concept of core-peripheries. These areas of study, sociotechnical transitions and core-peripheries, have remained relatively separate in the literature with little discussion regarding the potential of incorporating them. Murphy and Smith (2013) have begun this work by providing an application of the concepts to wind energy projects on the Isle of Lewis in Scotland. This study furthers this initial work by Murphy and Smith (2013) by proposing a theoretical framework that more thoroughly combines these concepts of sociotechnical transition and core-peripheries by pulling empirical evidence from a wider set of cases for a collective case study. This study's conceptual framework is shown in Chapter 4 Towards an Analytical Framework Figure 12 and extends the MLP by incorporating the related processes of peripheralization and centralization. The diagram in Figure 13 also presented in Chapter 4 Towards an Analytical Framework shows how the three levels of the MLP (landscape, regime, and niches) are a part of a geography by showing them as part of cores and peripheries. The first section of the Chapter 10 Analysis begins with an analysis of the case study sites in relation to the analytical framework. This is in part illustred by Figure 23 by showing how the analytical framework fits with the empirical cases of this study. This theoretical framework is complemented by the concept that core-peripheries niches and sociotechnical transitions are multi-scalar and 'nested' or 'embedded' within each other and that this perspective is a way to examine the relationships present at the various scales (shown in Figure 14 in Chapter 4 Towards an Analytical Framework). The scale is particularly important when examining the geographic relationships created by cores and peripheries during a sociotechnical transition because there are different relationships present at these various levels.

12.1.2. Research Question 2: Sociotechnical transition dynamics

The second research question of this study is,

2. What are the **sociotechnical transition dynamics** during a sociotechnical transition?

Research question 2 is addressed by examining sociotechnical transition dynamics that are being driven and shaped by policies, targets, and legislation with relation to the renewable energy transition in Scotland. Chapter 10.2 Transition Dynamics presents the results of the analysis that address this question. There has been a shift towards community-ownership in Scotland, in relation to land and resources such as renewable energy projects, that has been supported through policies, targets, and legislation. Legislation and policies can provide certainty and support for an industry and society but they are not static as they change over time due to changing landscape pressures. In the case of the recent energy related policy and subsidy changes made by the UK Government with closing certain subsidies early, the implications for onshore wind development in Scotland are large. The Scottish Government objected to this early closure to subsidies. The changes to subsidies have created a 'boom-bust' type effect (a part of the resource curse) on the industry as developers try to complete developments before the new end of subsidies. This geographically uneven disconnect between political will and support for renewable energy create complex dynamics within the UK. Although the changes to subsidy supports for schemes apply evenly across the UK, there is also an unevenness in the implications of such changes creating complex power dynamics.

12.1.3. Research Question 3: Core-periphery dynamics

The third research question relates to core-periphery dynamics,

3. What are the **core-periphery dynamics** during a sociotechnical transition?

Research question 3 is answered by examining the relationship dynamics between cores and peripheries over time as processes of peripheralization. As presented in Chapter 3 Resource Peripheries, three aspects of peripheralization include: relational, multi-dimensional processes, and multi-scalar. Chapter 10.3 Core-Periphery Dynamics presents the results of the analysis in relation to research question 3.

The relationships between locations (cores and peripheries) are relational as processes of centralization, re-centralization, peripheralization, de-peripheralization occur as noted by Kühn (2015). I build on this to suggest that there are also processes of re-peripheralization and de-centralization that can also occur. The relational aspect of peripheralization can be seen with respect to the changing relationship between cities (cores) and rural areas (peripheries) as renewable energy is developed in peripheries. The renewable energy resource is located primarily in the peripheries of Scotland however a large amount of the powers over the deployment of these resources are held in urban centres. This creates complex power dynamics between rural and urban areas as the flow of electricity (resource) is changing direction as renewable energy is developed in the periphery. There are also relational core-periphery power dynamics at governmental levels such as between the UK and Scottish Governments.

Multi-dimensional processes include the economic, social, political, and communicative dimensions and processes that occur over time. For example, as shifts in political will take place and support mechanisms change over time these shape the types of energy development that occur. There is a shift by the Scottish Government towards community and local ownership particularly with respect to renewable energy. This has been seen by the exceeding of Scottish Government targets (500MW by 2020) for community-owned or locally-owned renewable energy capacity in Scotland (The Scottish Government 2013a) and support schemes such as the Community and Renewable Energy Scotland (CARES) program. Another aspect of renewable energy development in peripheral areas is that of public awareness of energy production. People are becoming more aware of their energy production with renewable energy because of the dispersed and visual nature of some forms of renewable energy, such as wind.

Multi-scalar is the multiple scales at and between which the various processes and dynamics can occur (from global to sub-local). There are also multiple scales at which renewable energy is being developed in Scotland and this is involving processes of peripheralization and centralization. The scales where renewable energy developments are being developed and proposed are influenced by the framing of reasoning behind projects. For example with the Viking Windfarm proposal on Shetland, the scale of development is justified by the 'need' to export the electricity to support national targets and justify the cost to build an interconnector between Shetland and the UK mainland. The scale of renewable energy development in Scotland is having impacts on creating increased need for large-scale electricity storage. This can be seen with proposals such as the Coire Glas and expansion of the Cruachan pumped hydro storage schemes. This pumped hydro scheme proposal and expansion proposal are specifically to meet a certain scale of demand which is at the UK-level rather than the regional or local levels. This is a part of the trade-off between national benefit and autonomy as well as forms of green grabbing (discussed in Chapter 3 Resource Peripheries).

12.1.4. Research Question 4: Transition-periphery dynamics

The fourth research question links the dynamics of sociotechnical transitions with core-peripheries,

4. How are **sociotechnical transition dynamics** interlinked with **core-periphery dynamics** in the case of Scotland's transition to renewable electricity?

Research question 4 is answered by understanding the interlinking of sociotechnical transition dynamics and core-periphery dynamics as 'transition-periphery dynamics'. Chapter 10.4 Transition-Periphery Dynamics addresses this research question and presents the results of the analysis which discusses the history of electricity development in Scotland as well as niche and renewable energy development. As a part of the peripheralization processes there have been many types of sociotechnical transitions with respect to energy and other resources. This resource development and exploitation has shaped these peripheries through time. The electrification of the Highlands connected cores and peripheries in a new way with the infrastructure and flow of electricity created by this transition. The current renewable energy transition with respect to electricity is transforming this electricity system as the dominant direction of electricity flow and the shape of the system is changing to these new locations of electricity production.

There are many aspects to the transition-periphery dynamics in the renewable energy transition in Scotland. During a sociotechnical transition, the destabilizing of the regime can create windows of opportunity for niches (Fudge et al. 2015). The destabilizing or restabilising of a regime can include core-periphery dynamics. An aspect of peripheralization is shown through the sense of 'vulnerability' described by peripheral communities as changes take place to the regime and landscape. This is linked to a sense of lack of power by peripheral communities which is related in part to access to resources. Part of this lack of control is because peripheral communities are being 'influenced' by factors that they do not have control over.

A motivation for peripheries to develop niches and new technologies can be linked to some of the implications of periphery processes including this lack of power. Peripheries tend to be characterized as experiencing out-migration with populations moving to urban centres as well as low economic activity (Brown et al. 2000). Renewable energy development in peripheries is viewed as an income stream that can lessen the negative aspects of being a periphery such as processes of outmigration and gain control over their resources. To better understand transitions the core-periphery and transition dynamics can be examined together in order to create a better understanding of the transition-periphery dynamics.

12.2. Theoretical and Governance Implications

This study has theoretical implications as it presents a new analytical framework that incorporates concepts of core-periphery dynamics into the multilevel perspective from the sociotechnical transitions literature. This study confirms that the concept of transition-periphery dynamics is a way to better understand the complex geographical dynamics that occur throughout a sociotechnical transition as processes of peripheralization and centralization, or de-peripheralization or re-peripheralization occur.

This study addresses the need identified in the sociotechnical transitions field for further research that addresses the geographical aspects of transitions (Coenen et al. 2012; Hansen & Coenen 2013; Lawhon & Murphy 2011). Although this is a single study that presents a new analytical framework, it is a stepping stone for further study. Through literature reviews and empirical evidence from the collective case study this study developed an analytical framework. However this study does not directly apply the framework to cases although it would be a useful analytical tool. This contribution to theory allows for further research that will be able to build from this initial integration of these theoretical concepts in order for it to be refined and extended.

This study highlights the role of policies and how they are shaping the renewable energy transition. The results of this study have a number of policy implications and this study makes policy recommendations. These are in the context of an electricity system in the UK where there is beginning to be a change in flow of electricity as renewable energy is being developed from the periphery to cores rather than previously where electricity flow was primarily from cores to peripheries. This marks a critical change in the electricity system and has many implications both geographical and sociotechnical. This study argues for a systems approach by regulators and policy makers when designing policy and pathways to meet and set Greenhouse Gas (GHG) emission and renewable energy targets. This systems approach, as taken in this study, allows for a more clear and holistic understanding of the transition to renewable energy which is inherently complex. Setting targets such as with GHG emissions is relatively straightforward but it is the putting policies and support mechanisms in place that is more challenging as there are many ways for targets to be met. Scotland has decreased its GHG emissions by 39.5% between 1990 and 2014 (target of 42% by 2020) compared to the UK with 33% reduction (target of 34% by 2020) (Committee on Climate Change 2016). There is a need for longer term policy that supports renewable energy technologies particularly for technologies that require relatively large amounts of infrastructure and have longer 'pay-back' periods such as for hydro power. Policies relating to energy in the UK need to have more consideration for the implications of renewable energy development in rural areas. By understanding these areas as peripheries some of the negative aspects of the processes of peripheralization can be avoided as the renewable energy transition occurs. However, without the proper policy supports it is possible a sociotechnical transition to renewable energy will not be successful in the immediate future.

The 2016 referendum (Brexit) for the UK to withdraw from the European Union (EU) occurred after data collection was completed for this thesis. Brexit has potentially large implications for the energy system in the UK. The process of leaving the EU will have relatively limited implication in the short-term for the UK. However a certain amount of uncertainty has been created as withdrawal negotiations take place. Since the UK is connected through interconnectors to the electricity grids in mainland Europe the UK will likely continue to follow the rules of the EU grid rather than make them. However, in the long-term it is uncertain whether the EU targets will be integrated into the national (UK) level.

Community-owned renewable energy developments are a way for communities to become empowered and involved in the development of their peripheral resources. There has been support by the Scottish Government for increased community and local ownership particularly with respect to renewable energy. This has been shown through Scottish Government targets that were exceeded for community-owned or locally-owned renewable energy capacity in Scotland (The Scottish Government 2013a) and programs such as the Community and Renewable Energy Scotland (CARES) program. However, the possible forms of public and community-ownership of parts of the energy system are limited by the current liberalized energy market.

As noted in the Chapter 10 Analysis, peripheral communities often feel a ‘lack of control’ and community-owned renewable energy development schemes are one way to reassert control. This adjusts the core-periphery power dynamics. Currently the way in which renewable energy is often developed it is being ‘exported’ to cores and these peripheries have limited sense of control or ownership of these resources. The development of renewable energy in the peripheries of Scotland is an opportunity for these areas. Development of this peripheral resource can be controlled and developed at the national-scale with national-scale priorities or more locally. Energy developments and infrastructure such as interconnectors are ‘nation building’ and can often be prioritized over local-scale priorities. However, as is occurring in some parts, the resource can be developed for local-consumption by the peripheral areas for use within these areas with potential export to cores. Community-owned development of resources at a large-scale for export can also occur however these are less common under current market conditions and support mechanisms. Proposals such as the Viking Windfarm on Shetland are an example of a large-scale renewable energy export project however it is only partially community-owned (45%). However, peripheries are often challenged by the poor infrastructure that connects them to cores such as with limited transmission infrastructure and interconnectors to islands. This infrastructure challenge in a sense 'protects' these places from large-scale development to some extent although it also leads to framing of renewable energy development as binary, with large-scale development requiring an interconnector for large-scale export versus limited small-scale development. This is problematic because it limits the ways in which potential pathways for development are viewed particularly for local communities who feel a lack of control and this should be addressed by policy makers in order to minimize this effect.

12.3. Study Limitations

There are a number of limitations and challenges of this study. Sociotechnical transitions research is inherently challenging because transitions occur over significant time frames (25 years or more) as noted by Farla et al. (2012). This study examines a potential sociotechnical transition in mid-transition which limits the insights that can be derived as compared to studying a fully completed transition. This can be overcome to some degree by incorporating historical insights. This study includes some historical insights through the discussion of the electrification and hydroelectricity development in the Highlands (1940s to 1950s) and past resource development on Shetland.

The study is also limited by its scope with a limited number of cases as a collective case study in order to better understand broader processes and dynamics. The limited number of cases leads to a common criticism of the case study approach which is the extent to which a single or small number of cases can be representative in order for findings to be derived and applied more generally (Bryman 2012; Tellis 1997). Hansen and Coenen (2015) note a weakness of many geographical analyses of sociotechnical transitions that they focus on distinctive cases of specific locations which leads to it being difficult to, "identify and formulate insights with theoretical purchase" (Hansen & Coenen 2015, p.3). This study is limited to a number of cases however the thick description acquired for each of the cases and for the regime and landscape levels allow for this study to make wider theoretical and policy generalizations and recommendations.

Another limitation of the case study approach is that there is an inevitable selection bias when selecting cases. Practicality of resources or access can limit or determine the cases instead of what would be best from a research perspective. Researchers also have personal biases and perspectives on case studies possibly as insiders or outsiders depending on the case. Therefore I tried to be reflective of personal biases and position as an outsider within the case sites (Cousin 2005).

There are also constraints with the semi-structured interview methods of this study. There is a temporal constraint because interviews took place from January 2015 to April 2016 and therefore findings are specific to this time period. There is also the possibility that the number of key informants that were interviewed was too small to gather all the required information and may not represent the views of the majority of the community (Marshall 1996). However, in order to avoid this interviewees were selected based on Marshall's (1996) criteria: their role within the community, knowledge base, willingness to cooperate/participate, good communication skills, level of bias and objectivity (as described Chapter 5 Methods). Additionally, there is always the potential of misinterpretation of interviews. The large quantity of data in this study could have made it difficult for the researcher to identify all of the important pieces of information or factors in the cases (Cousin 2005). This can lead to relationships and causations being missed when creating generalizations from data. This is added to by the fact that sociotechnical transitions are inherently complex and it is difficult to identify key features and dynamics. However, this is avoided through the development of the analytical framework (presented in Chapter 4 Towards an Analytical Framework) developed through this study. Also, the MLP is operationalized in Chapter 6 Existing Energy Systems as a heuristic device by using the three levels of the MLP. Although these study limitations are present, the results of this study offer valuable insights into theory and policy.

There are challenges and limitations with the combined framework presented in Chapter 4 Towards an Analytical Framework which answers the first research question of this study. These are discussed in detail in the analytical framework chapter in subsection 4.5 Challenges and Limitations. The conceptual framework of this study shown in Chapter 4 Towards an Analytical Framework in Figure 12 extends the MLP by incorporating the related processes of peripheralization and centralization within core-peripheries. Broadly there are priorities and trade-offs with any model or framework which inevitably must simplify a system or narrative. More specifically there are challenges involved with incorporating concepts from different fields, in this case, human geography (core-periphery) and innovation studies/STS (sociotechnical transitions). This could, "create considerable ambiguity" as suggested by Hansen and Coenen (2015, p.3) when combining geographical aspects with sustainability transitions frameworks. Hansen and Coenen (2015) also warn of haphazard or fuzzy conceptualisations result from 'external' ideas being imported and translated into the sociotechnical transitions field. As well there can be confusion over dissimilar meanings to similar terms or vice versa (Hansen & Coenen 2015). This issue of terms holding various meanings is one of the difficulties examining the geographical aspects of the MLP because of terms such as 'landscape', which within the transitions literature is not spatially explicit, but holds a very different meaning within geography. This creates an issue of clarity that is difficult to avoid with interdisciplinary research. The primary tactic to reconcile these ambiguities is in 4.2 Key Terms where a set of key terminology is outlined in order to avoid confusion over the potential various meanings of certain terms which can be an issue with interdisciplinary research.

12.4. Transition-Periphery Dynamics around the World

There are renewable energy projects being developed throughout the world as part of sociotechnical transitions with transition-periphery dynamic implications. For example, these developments can take the form of large-scale controversial projects.

Controversies often centre on: land use change, place-attachment, visual impacts, ownership, and benefits. These large-scale projects frequently involve transmission infrastructure such as subsea interconnectors as shown with the proposed Viking Windfarm already discussed in this study.

Other cases with similar transition-periphery dynamics are present worldwide. An example of one of these large-scale renewable energy projects already developed is that of the Upper Churchill Falls Hydropower Project (5.4GW) in Labrador, Canada, which is the second largest hydroelectric project in Canada (Boksh 2015). Plans for additional hydroelectric power development in the region is underway with the Muskrat Falls project (0.8GW) which began planning in the mid-1960s and the project was sanctioned in 2012 by the provincial government. Both of these projects are in Lower Churchill involving 1,100km (684mi) of high-voltage direct current (HVDC) transmission line infrastructure.

The main controversial aspect to the Upper Churchill Falls project is that the, "major share of power and benefit" (p.39) is by Hydro Quebec who is the public utility manager for electricity generation, transmission and distribution in Quebec (Boksh 2015). Quebec receives the majority of the benefits rather than the benefit going to the province of Newfoundland and Labrador where the project is geographically located. The majority of the power must be sold to Hydro-Quebec at an 'extremely low price' because of an agreement signed when the project was developed (Feehan & Baker 2010, p.65). The Newfoundland and Labrador provincial government have challenged the contract since the mid-1970s through public opinion appeals and appeals to the Supreme Court which failed. The ownership of the project will return to Newfoundland and Labrador in 2041 (Boksh 2015). The project has been contentious with protests around the development's lack of direct benefits for the province of Newfoundland and Labrador. Feehan and Baker (2010) describe how this is, "another case where the province's resources have been exploited by outsiders" (Feehan & Baker 2010, p.65). This is a case where the province of Newfoundland and Labrador, where these large-scale hydro developments are located, can be understood as peripheries to the larger province of Quebec where this energy is mainly being exported to. It also demonstrates the long-lasting impacts of such developments with the infrastructure investment and importance of control in relation to acquiring the benefits of such development within the periphery.

The UK electricity supply sector and other electricity sectors around the world are facing the challenge of decarbonisation which is not only a supply and demand challenge, it is also a challenge of energy storage (Wilson et al. 2010). These sectors have transition-periphery implications that are also sociotechnical. Pumped hydro storage is the only current proven technology for large-scale storage of electricity. However, pumped hydro storage is limited to specific geographic constraints such as needing a considerable elevation difference between a lower and upper reservoir.

New forms of large-scale energy storage are being developed such as compressed air energy storage, pumped cryogenic electricity storage, and seawater pumped hydro storage. Compressed air energy storage technology began to be developed in the 1970s and has potential as large-scale network storage of energy (Matos et al. 2015). The technology is currently a demonstrated technology with the Huntorf Plant (Germany) and McIntosh Plant (US). Huntorf was built in 1978 with a capacity of 290MW with two salt caverns meant to provide black start services for nuclear power stations (Matos et al. 2015). The McIntosh Plant became operational in 1991 with 110MW and utilizes a salt dome (Matos et al. 2015). Pumped cryogenic electricity storage stores energy by chilling air into its liquid phase and generating power when it warms and therefore expands. There are plans for a 5MW pumped cryogenic energy storage scheme near Manchester by Highview Power Storage (Letcher 2016). The only seawater pumped hydro storage system in the world became operational in 1999 in Okinawa Island, Japan with 30MW capacity (Rehman et al. 2015). There are proposals for other seawater pumped hydro storage projects such as the Dead Sea Power Project (1500MW-2000MW) on the Dead Sea and in Glinsk, Ireland a proposal for a 480MW project (Rehman et al. 2015). There are also smaller-scale storage technology developments such as with a proposed developed in Germany by General Electric to integrate pumped hydro storage inside individual wind turbines; integrating source and storage. These are just a handful of relatively new forms of technology for energy storage however there are many others being developed. The need for large-scale energy storage will continue to increase if further intermittent renewable energy is further developed large-scale and centralized. This increasing need is likely to continue with the GHG emission and renewable energy targets that have been adopted at varying degrees by the majority of countries in the world (IRENA 2015).

The implementation of targets for GHG emission reduction and renewable energy development is critical in order to address climate change. With these targets and the policies that accompany them we need to be aware of the transition-periphery dynamics and implications from developing renewable energy in different ways in these regions. There are many ways in which these targets can be met. The Scottish Government has what has been described as showing, “strong climate leadership” (Nelson 2013, p.18) through ‘ambitious’ targets for reducing GHG emission (40% reduction by 2020 from 1990 levels) (Bergmann & Hanley 2012). These targets focus on the electricity sector with the target of 100% of Scotland’s electricity demand from renewable sources by 2020 (The Scottish Government 2013a). The Scottish Government’s targets for renewable energy development for other sectors are significantly lower with heating at 11% and renewable transport at 10% by 2020 (Scottish Government 2011). These Scottish targets are relative to others such as the EU 20-20-20 targets for 2020 with 20% energy consumption from renewable, 20% GHG emission reduction, and 20% primary energy use reduction (through energy efficiency). Other countries around the world have varying targets such as Australia with 41,000 GWh (estimated 20% of demand) of electricity from renewable energy sources by 2020 or South Africa with a target of 17.8 GW of renewable energy capacity by 2030 (IRENA 2015). According to the International Renewable Energy Agency (IRENA) (2015) since the emergence of renewable energy targets in the 1970s, the number of countries with renewable energy targets has increased from 43 countries in 2005 to 164 in 2015.[90] This increasing use of targets in relation to renewable energy highlights the importance of understanding these drivers and implications for the transition-periphery dynamics these targets will have around the world at various scales. This concept of transition-periphery dynamics can also be

[90] IRENA (2015) define renewable energy targets as “numerical goals established by governments to achieve a specific amount of renewable energy production or consumption. They can apply to the electricity, heating/cooling or transport sectors, or to the energy sector as a whole” (p.8).

applied beyond energy transitions and climate change to other forms of transitions in order to better understand their geographic aspects.

12.5. Recommendations for Future Research

There are a number of recommendations this study makes for future research in terms of future development of theory and application of the analytical framework developed by this study. More research is needed to examine other energy systems such as for transport and heating with respect to sociotechnical transitions. Although these other systems may be at earlier stages of potential transition, it would be highly valuable to begin examining particularly the transition-periphery aspects of these systems. This study examines the electricity system rather than other forms of energy because the focus of targets and policies thus far have been on electricity even though it is not the greatest contributor to GHG emissions in the UK (DECC 2014c). It has been noted that the area where most progress with regards to carbon reductions has been electricity production and that there is further scope for further reductions (Geels 2014). The progress made in the electricity system with carbon reductions is a reason for further research about the ongoing transition of the electricity system and also the other energy systems where a transition to reduce GHG emissions may be more difficult or complex.

The analytical framework developed in this study has potential for further application. Further research could apply the analytical framework developed in this study to other cases. This would aid in refining the analytical framework presented in this study. This framework could also be applied to other types of sociotechnical transitions than that of energy transitions. Additionally it could be applied to historical sociotechnical transitions in order to examine a complete transition and its multi-scalar aspects and processes of peripheralization and centralization. The examination of historical case studies is common in sociotechnical transition studies (Turnheim & Geels 2012) and this has the advantage that they generally are completed historical events thus allowing the entire process to be examined.

The concept of transition-periphery dynamics could benefit and be complemented by being incorporated with the relatively new social science research agenda of energy justice. Energy justice applies principles of justice to energy systems, policy, security, and climate change (Jenkins et al. 2016). In particular issues of distributional justice[91] in terms of energy production and consumption is an area of research that closely ties into issues around transition-periphery dynamics. It is important as Dalglish et al. (2017) describes, the 'deeply-embedded historical injustices' in Scotland relating to the land and resource development are studied further to ensure that they are not being perpetuated but challenged. This is also noted by Haf and Parkhill (2017) that, "contemporary energy developments might very well be replicating historical experiences of dispossession and disempowerment imposed on peripheral communities and indigenous communities" (p.105) as part of unjust energy processes. However, renewable energy development by communities can be a way for these communities to become more sustainable and empowered as this research shows (Haf & Parkhill 2017).

This study highlights the importance of geography within a sociotechnical transition and urges future research to continue to focus on these complex geographic processes. This research presents one way in which the MLP can be adapted to include geographical concepts with that of processes of peripheralization and centralization within multi-scalar levels. It is important that research continues to integrate other geographical concepts and approaches with sociotechnical transitions because there are many different ways the geographical aspects of sociotechnical transitions can be understood. The concepts of peripheralization and centralization have been applied to geographic relationships that are a part of an energy sociotechnical transition in this study; however, these concepts could also be applied more widely such as to gender studies, economics, health studies, and anthropology.

[91] Distributional justice is a type of energy justice that "recognizes both the physically unequal allocation of environmental benefits and ills, and the uneven distribution of their associated responsibilities" (Jenkins et al. 2016, p.176). Jenkins et al. (2016) also identify recognition and procedural types of energy justice.

Appendices

Appendix 1 List of type of interviews and interview number

MLP Level		Type	Interview Number
Case level	Case 1 North Yell Tidal Scheme	Manager of a community development organization on North Yell, Shetland	1
		Energy company employee, Shetland	2
		Scottish Government development agency area manager, Shetland	6
		Scottish Government development agency employee	7
		Energy company projects manager, Scotland	8
		Scottish Government development agency director in relation to energy	9
		Renewable energy company founder and director, Scotland	10
	Case 2 Shetland Interconnector	Community development organization manager, Shetland	1
		Energy company employee, Shetland	2
		Not-for-profit community organization vice-chair, Shetland	4
		Wind energy company manager, Shetland	5
		Scottish Government development agency area manager, Shetland	6
		Scottish Government development agency employee	7
		Energy company manager, Scotland	8
		Scottish Government development agency director in relation to energy	9
	Case 3 Coire Glas	Local authority planner, Scotland	11
		Not-for-profit policy officer, Scotland	12
		Energy company development manager, Scotland	14
	Case 3 Cruachan	Local authority planner, Scotland	11
		Energy company engineering manager, Scotland	13
		Scottish Government environmental regulator hydro specialist, Scotland	15

Regime and Landscape	Scottish Government development agency Area Manager, Shetland	6
	Scottish Government development agency director in relation to energy	9
	Local authority planner, Scotland	11
	Not-for-profit policy officer, Scotland	12
	Scottish Government environmental regulator hydro specialist, Scotland	15
	Scottish Government agency renewable energy policy officer	16
	Industry representative body policy officer, Scotland	17
	Lawyer involved in energy policy, Scotland	18
	Lawyer involved in energy policy, Scotland	19
	EU lobby group policy and market analyst	20
	Scottish Government policy officer	21
	Scottish Government development agency director in relation to energy	22

Appendix 2 Interview Protocol

Title: Renewable Energy and Transition-Periphery Dynamics in Scotland
Principal Investigator: Fiona Munro, PhD Student, School of Interdisciplinary Studies, College of Social Sciences, University of Glasgow

Introductory Statement
In order for this interview to be transcribed I would like to audio-record our conversation today. Only my supervisor and I will have access to these recordings and they will be destroyed at a later date. You must sign the Consent Form to meet the University of Glasgow ethics requirements to partake in this study which states: all information will be held confidential, participation is voluntary, and you may stop the interview at any time. Thank you again for participating.

The interview is planned to take thirty minutes to an hour. I have a set of questions I would like to cover.

This study is examining the shift towards renewable energy in Scotland to better understand the relationship-dynamics and geographical aspects of this type of energy transition.

INTERVIEW QUESTIONS
Interviewee Background

Interviewee (Title and Name): ____

Level (case study/niche, regime, landscape): _________________________________

Relevance of Interviewee: ____

Empirical
Background

I. How did the renewable energy project come about?

Influences and Pressures

II. What were the main influences/pressures on how the project came about and developed (such as policies, organizations, institutions)? Are these internal or external?

III. Where did these influences/pressures come from and how did these influences/pressures operate and shape the development?

Challenges

IV. What were the key challenges? Any current or future challenges?

Wider Reflections
Status

- What is the status of the shift in the energy sector towards renewable energy?

Pressures and Powers

- What are the main powers within and pressures on the energy sector to develop in certain ways and with certain technologies?

- What are the relationships between the different powers involved in energy development? How do these relationships change over time?

- Will devolution in Scotland and other parts of the UK affect these powers?

- How has public policy affected the development of [insert 'renewable energy' or the renewable energy 'case study'] (push, inhibitor, etc)?

- What are the main influences on public energy policy relating to renewable energy development?

- Has there been any push from the [insert 'community' or 'organization'] to have the policy around energy changed in any specific way?

- What do you think is the future of the renewable energy case study? Further renewable energy development in the area and further afield?

Suggestions of other potential interviewees___________________________________

Appendix 3 Plain Language Statement

University of Glasgow | College of Social Sciences

Plain Language Statement

Title: **Renewable Energy and Transition-Periphery Dynamics in Scotland**

Principal Investigator: Fiona Munro, PhD Student, School of Interdisciplinary Studies, College of Social Sciences, University of Glasgow
Email: *f.munro.1@research.gla.ac.uk*

Supervisor: Prof. Joseph Murphy, School of Interdisciplinary Studies, College of Social Sciences, University of Glasgow
Email: *Joseph.Murphy@glasgow.ac.uk*
Phone: 01387702039

We would like to invite you to take part in this research study 'Renewable Energy and Transition-Periphery Dynamics in Scotland'. It is important that you understand what participating in this study will involve and why the research is being done before deciding whether to take part. Please ask us for any additional information or if something is not clear. Please read the following information carefully and you are welcome to discuss it with others. Take your time in deciding whether or not to participate in this study.

Thank you for your time and reading this.

Purpose

The purpose of this study is to examine the relationships and dynamics created by the shift to renewable energy development in the rural parts of Scotland. The results of this research will contribute to generating understandings and inform policy around renewable energy development in Scotland. It will also allow the Prinicpal Investigator (Fiona Munro) to fulfill the requirements of a Doctor of Philosophy (PhD) at the University of Glasgow.

Interviews will take place between Jan. 15th, 2015 and April 1st, 2016.

Participants

Participants have been chosen based on their knowledge and experience with renewable energy. Contact information for recruited participants will be obtained through information considered to be in the general public domain. Roughly thirty to fifty participants are expected to take part in this study. Participation is entirely voluntary and it is your decision of whether to take part or not. If you do decide to participate in this study, you can withdraw at any time and you do not have to give a reason. The interview will last no longer than two hours with the Principal Investigator. Open-ended interview questions will be asked about renewable energy which will be recorded with an audio-recorder to be transcribed at a later date.

Confidentiality
Data collected from in person interviews will, to the best of the abilities of the Principal Investigator, maintain confidentiality of your name and the contributions you have made to the extent allowed by the law. Any information about you that has your address or name will have your address or name removed and a pseudonym assigned so that you cannot be recognised from it. Due to the nature of small communities in which this study in part takes place, there may be implications for maintaining anonymity because it could make it easier for you to be identified even though pseudonyms will be used.

The transcript and audio-files from the interview will be stored in a secure location at the University of Glasgow, electronically on a password protected computer and as a paper copy kept in a locked filing cabinet. Data (transcripts and audio-recordings) will be destroyed through the deletion of the electronic copy and shredding of the papery copy ten years following the completion of the Principal Investigator's degree.

Results
Data collected from these interviews will be transcribed and analysed. The process will then be reflected on by the Prinicipal Investigator and written up in the form of a thesis to be submitted to the Principal Investigator's supervisor (Prof. Murphy) and committee at the University of Glasgow. Other publications such as in the form of journal articles may also be written from this research and published. A written summary of roughly 500-1000 words of the study's results and conclusions will be made available to participants on request by contacting the Principal Investigator. You will not be identified in any report/publication by name, but quotes with a pseudonym may be used.

Funding
The Principal Investigator is funded through the University of Glasgow by the Lord Kelvin & Adam Smith Scholarship 2013-2017.

Contact for Further Information
If you have any concerns or would like additional information feel free to contact the Principal Investigator (Fiona Munro) or the Supervisor (Prof. Murphy), contact information at the beginning of the first page.

You can also contact the College of Social Sciences Ethics Officer:
Dr. Muir Houston
Email: *muir.houston@glasgow.ac.uk*
Mobile: 01413304699
The College of Social Sciences Research Ethics Committee at University of Glasgow has reviewed and approved this project.

Appendix 4 Consent Form

University of Glasgow | College of Social Sciences

Consent Form

Title: **Renewable Energy and Transition-Periphery Dynamics in Scotland**
Principal Investigator: Fiona Munro, PhD Student, School of Interdisciplinary Studies, College of Social Sciences, University of Glasgow

1. I confirm that I have read and understand the Plain Language Statement for the above study and have had the opportunity to ask questions.

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

3. *What you will be required to do:* Engage in an open-ended discussion based on the interview questions, lasting no longer than two hours with the Principal Investigator concerning renewable energy. Information on the project will be provided before the interview and consent will be obtained before the interview is conducted.

   Statement of confidentiality: Data from in person interviews and observations will, to the best of the abilities of the Principal Investigator, maintain confidentiality of your name and the contributions you have made to the extent allowed by the law. Names will not be disclosed and a pseudonym will be used for each participant.

   Data collection and disposal: Interviews will be recorded with an audio-recorder to be transcribed at a later date. The transcript and audio-files from the interview will be stored in a secure location at the University of Glasgow, electronically on a password protected computer and as a paper copy kept in a locked filing cabinet. Data will be destroyed 10 years following the completion of the Principal Investigator's PhD degree (expected August 2016 completion).

4. Your signature indicates that you understand the risks and contributions of your participation in this study and agree to participate.

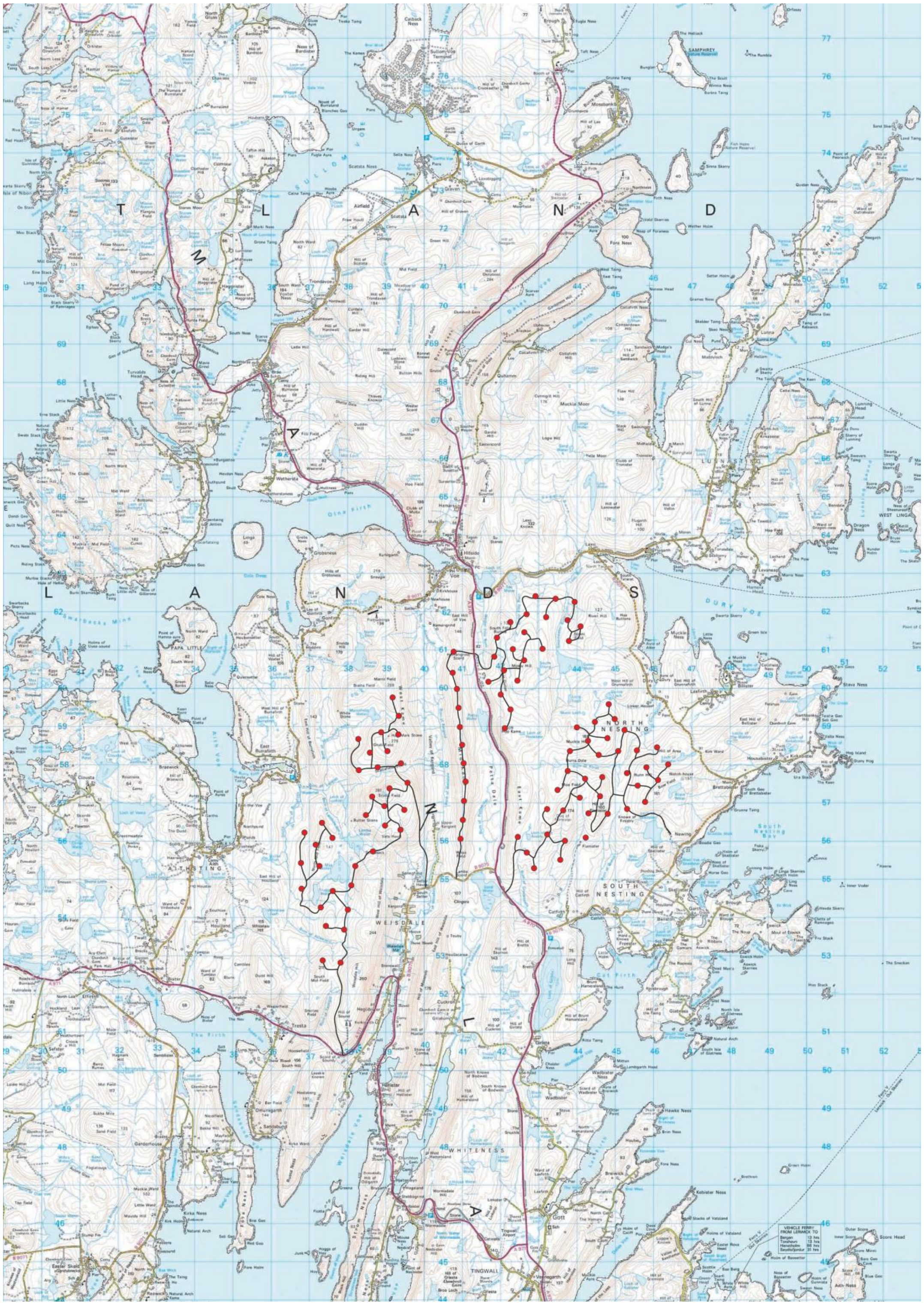
______________________	__________	______________________
Name of Participant	Date	Signature
______________________	__________	______________________
Principal Investigator	Date	Signature

Appendix 5 List of policy documents

Policy Level	**Document**
Council	The Argyll and Bute Community Plan 2009 – 2013. Argyll and Bute Community Planning Partnership, 2009.
	Argyll and Bute Renewable Energy Action Plan – 2010 to 2013 Powering Scotland’ s Future, Argyll and Bute Council, 2009.
	Shetland Structure Plan 2001-2016, Shetland Islands Council, 2000.
	Shetland Local Plan: Yell Community Council Area Statement, Shetland Islands Council, 2004.
	Renewable Energy Development in Shetland: Strategy and Action Plan, Shetland Islands Council, 2009.
	Economic Development Policy Statement 2013-2017, Shetland Islands Council, 2014.
	Our Corporate Plan 2013-2017, Shetland Islands Council, 2014.
	Highland Renewable Energy Strategy and Planning Guidelines, The Highland Council, 2006.
	South Planning Applications Committee, The Highland Council, 2012.
Regional	Building Our Future: Operating Plan 2015-2018, Highlands and Islands Enterprise, 2016.
	Building Our Future: Operating Plan 2016-2019, Highlands and Islands Enterprise, 2016.
Scotland	Renewables Action Plan. Renewable Energy, Scottish Government, 2009.
	Scottish Planning Policy, Scottish Government, 2010.
	2020 Routemap for Renewable Energy in Scotland, Scottish Government, 2011.
	Scottish Islands Renewable Project Final Report, Scottish Government, 2013.
	2020 Routemap for Renewable Energy in Scotland, Scottish Government, 2013.
	Scotland’s Future: Your Guide to an Independent Scotland, Scottish Government, 2013.
	Community and Renewable Energy Scheme - Overview of Support, Scottish Government, 2014.
	Energy in Scotland 2017, Scottish Government, 2017.
UK	National Renewable Energy Action Plan for the United Kingdom: Article 4 of the Renewable Energy Directive, DECC, 2009.
	The UK Low Carbon Transition Plan, DECC, 2009.
	The UK Low Carbon Transition Plan: National Strategy for Climate and Energy, DECC, 2009.

	Providing regulation and licensing of energy industries and infrastructure, DECC, 2012.
	Renewable electricity in Scotland, Wales, Northern Ireland and the regions of England in 2012. In Special feature- Sub-national renewable electricity, DECC, 2013.
	UK Renewable Energy Roadmap Update 2013, DECC, 2013.
	UK Renewable Energy Roadmap Update 2013, DECC, 2013.
	Community Energy Strategy: Full Report, DECC, 2014.
	Community Energy Strategy: People Powering Change, DECC, 2014.
	UK Energy in Brief 2014, DECC, 2014.
	Review of the Feed-in Tariffs, DECC, 2015.
	UK Energy Statistics, DECC, 2016.
	Policy: Increasing the use of low-carbon technologies, Government of the United Kingdom, 2014.
	The renewable energy sector in Scotland: First Report of Session 2016-17, House of Commons Scottish Affairs Committee, 2016.
	Energy Bill: Explanatory Notes on Lords Amendments, House of Lords, 2013.
Europe	Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Energy Roadmap 2050, European Commission, 2011.
	Energy Roadmap 2050 European Commission, 2015a. 2030 Energy Strategy, European Commission, 2012.
	Communication from the Commission to the European Parliament, the Council, the European economic and social Committee and the Committee of the Regions - A policy framework for climate and energy in the period from 2020 to 2030, European Commission, 2014.
	Energy Union Package, Communication From the Commission to the European Parliament and the Council, European Commission, 2015.
	The EU climate and energy package, European Union, 2014.

Appendix 6 Map of the Viking Windfarm proposed sites for wind turbines on the Central mainland of Shetland (Source: Viking Energy n.d.)**.**



Glossary

Baseload	Baseload is the minimum demand level of an electrical grid. This demand is met by power stations that generate electricity at a constant rate (e.g. nuclear power stations) (P. L. Younger 2014). This is one type of electricity production capacity with the others being variable and flexible (European Commission 2011).
Black Start	A black start is when a power station needs electricity in order to start generating power if starting from completely turned off.
Capacity Factor	The capacity factor is the ratio of the amount of electricity produced over a given time divided by the amount of electricity that could be produced if running at full capacity. For example with wind energy the wind source is intermittent therefore capacity factors tend to be significantly lower than other non-renewable sources of energy. Factors that affect this ratio include operational, maintenance, and environmental conditions (Nelson 2013).
Case Study	A case study is, "the detailed and intensive analysis of a single case" (Bryman 2012, p.66). A case is most commonly considered to be a location, community, or organization (Bryman 2012). A case can also be "an instance of a class of events" (George & Bennett 2005).
Collective Case Study	The Collective Case Study is a type of case study outlined by Stake (1995) that involves a group of cases to makeup a single case study.
Community	Community can be defined in multiple ways however it often it is specially defined however it can also be through other ways such as self-identification. Scotland tends to define communities geographically with respect to energy developments.
Core	Cores can be understood to be cities, regions, or countries and are centres of technological, economic and social innovation. Cores are areas that have developed faster than peripheries as cores exploit the peripheries through migration or resource exploitation.
Dispatchable	Dispatchable is electricity capacity that is flexible in that it can adjust its level of power output relatively quickly to meet variation in demand (P. L. Younger 2014). For example at times of high electricity demand these sources

	can be adjusted to increase or decrease output (e.g. hydro electricity).
Dynamic	Dynamic is the constant change and activity that characterizes a process or system.
Energy Density	Energy density is a measure of the energy per unit volume of fuel (P. L. Younger 2014). It can be measured in watts per square meter or joules per square meter.
Environmental Determinism	The concept that the physical environment constrains and determines society activities, social and economic, is known as environmental determinism. Environmental determinism has been used as a theoretical guide by which to make generalizations. The concept was based on Friedrich Ratzel's theories around nature-culture relationships, and was brought into mainstream academia by Ellen C. Semple (1911) (Frenkel 1992).
Green Grabbing	Green grabbing is "the appropriation of land and resources for environmental ends" (Fairhead et al. 2012, p.237).
Inductive	An inductive approach, also called the 'bottom up' approach, works from specific observations where patterns are identified, that then build to broader generalizations and theories.
Installed Capacity	Installed Capacity is the amount of power generation a facility (e.g. wind farm, solar array, power plant) is able to produce at full production and is often measured in megawatts (MW) or gigawatts (GW). It can also be described as 'peak output' (P. L. Younger 2014).
Interconnector	Interconnectors link networks and allow energy to flow between them. They can link parts of the electricity system at the regional or national scale. Interconnectors can be subsea, over ground, or underground.
Landscape	Landscape as a geographical concept is a fixed location (longitude and latitude) as well as a relative place which is highly dynamic with emotional attachments (Bridge et al. 2013). Landscape is also one of the three levels of the multilevel perspective (MLP) where landscape is the context and external factors in which interactions and changes occur (Geels 2002).
Middle Range Theory	Middle Range Theory was introduced by Merton (1968) as an alternative to grand theory and abstracted empiricism. Middle Range Theory is defined by Merton (1968) as "theories that lie between the minor but necessary working, hypotheses that evolve in abundance during day-to-day research and the all-inclusive

	systematic efforts to develop a unified theory that will explain all the observed uniformities of social behaviour, social organization and social change” (p.39).
Multilevel Perspective	The multilevel perspective (MLP) is an approach to understanding sociotechnical transitions (Geels 2002; Genus & Coles 2008; Markard & Truffer 2008; Rip & Kemp 1998; Smith & Stirling 2010). In the MLP approach there are three levels of a sociotechnical transition: niche (micro level), regime (meso level), and landscape (macro level).
Multi-scalarity	Multi-scalarity has been utilized to understand the different spatial scales of phenomenons.
Niche	Niches are one of the three levels of the multilevel perspective (MLP) that are locations that protect and nurture radical innovations from the regime (Geels 2010).
Normative	The normative social science approach acknowledges the bias and subjectivity of research. It also makes statements about the way things should be.
Periphery	Periphery is “defined by its relation of dependency to the core” (Friedmann 1967, p.22). Peripheries and cores develop over time through complex processes that create core-periphery relationships.
Place	Place is a geographical concept with three dimensions: locale, location, and individuals’ associated senses or affects (Murphy 2015). This is in contrast to location which is fixed with simply a longitude and latitude (Bridge et al. 2013).
Regimes	Regimes are one of the three levels of the multilevel perspective (MLP) that encompass the dominant practices, rules, and shared assumptions that guide activities within communities (Rotmans et al. 2001).
Resource	Resource can be understood as, “a thing or a substance but to a function which a thing or a substance may perform or to an operation in which it may take part” (Zimmermann 1951, p.7). Resources are made through value being placed on a part of the environment.
Resource Periphery	Peripheries tend to be characterized as having relatively large amounts of resources where resource making and destruction occur, therefore these areas can be understood as ‘resource peripheries’. The concept of resource peripheries has been implicitly and explicitly applied to a range of settings (Murphy & Smith 2013).

Scale	The concept of scale is the spatial level such as from local to global. Scale in the context of sociotechnical transitions can be understood as, "the analytical dimension used to measure and study any phenomenon (e.g. time, structure and space)" (Raven et al. 2012, p.65).
Social Constructionism	Social Constructionism is a theory where reality is understood as a social construction where knowledge is socially and culturally constructed through human interaction (Kim 2001).
Sociotechnical Transition	A sociotechnical transition is the change from one sociotechnical regime to another (Geels & Schot 2007). This involves the transformation over time of a sociotechnical system and the diffusion of a radical innovation.
Space	Space has different forms such as physical (e.g. territorially bounded places) and relational, which emerge from interactions between social or economic entities (Raven et al. 2012). Space as a relational concept is related to how actors interact and the distance between them (Coenen et al. 2012).
System	A system is a group of things that regularly interact or are interdependent. These items makeup a complex whole.
Technological Determinism	Technological determinism (as known as technical determinism) is the concept that, "technology develops as the sole result of an internal dynamic, and then, unmediated by any other influence, molds society to fit its patterns" (Winner 1995, p.29).
Throughput	The amount of oil that goes into the terminal to be processed as opposed to the amount that the terminal produces after processing.
Utilitarian Approach	The utilitarian approach is based on political theory and is an ethical stance. This approach is used to prioritize certain groups or individuals. For example the goal or what is considered 'best' can be what favours 'the greatest number of people' or 'the most powerful entities' or the 'greatest number of species'.
Voe	Voe A voe is a narrow bay or inlet in Shetland or Orkney.
Voltage	Voltage is a measure of the difference of electrical energy between two points. The larger the difference between the two points, the larger the voltage. Voltage is measured in volts (V).

Watt	Watts are a measure of power and are the rate of energy use in joules per second (P. L. Younger 2014). Joules are a measure of the available amount of energy from a certain quantity of fuel. Watts are often used with the prefixes ‘kilo-’, ‘mega-’, ‘giga-’, and ‘tera-’ and represented as kW, MW, GW, and TW.

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