How do regional characteristics influence sustainability transitions?

An analysis of marine energy in Wales.

By

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Abstract

This thesis adds to literature that explores the geography of sustainability transitions, seeking to understand how regional characteristics influence innovation and ultimately a shift towards more sustainable forms of energy. The research focuses on the role of actors in supporting these processes and the activities that might be undertaken to draw down regional economic benefit. To do so, the analysis draws upon transition studies to analyse major reconfigurations in the way societal functions are delivered, complemented with insights from geography and innovation literatures to understand how spatial aspects influence the technology trajectory and new path creation.

Uniquely, the research evaluates the trajectory of a technology that is navigating a pre-commercialisation path that cannot yet be concluded to be a success or failure. A 'transition in action' is investigated through an analysis of the marine energy industry in Wales, a devolved nation where numerous pre-commercialisation technologies are in development. The case study utilises data gathered through interviews, policy document analysis, and Q Methodology to identify the regional factors that influence change.

The thesis advances understanding of transition through establishing that in the context of a less-developed region, declining industry and the prospect of its continuation or demise dictates how actors mobilise their resources - showing that the economic development status of a region has a significant impact on change. The research finds that how actors connect, the quality of their relationships, and how knowledge is shared are paramount. Further, in the case study context of a less-developed region, the research challenges innovation theory, showing that transition is still possible with a low number of actors and limited financial resources, but more social and political action is required as a result. In doing so, the research adds to understanding of the agency of these actors and the roles that might be fulfilled, which include intermediation, the building of knowledge networks, and advocating for the institutional realignment required to bring about societal change.

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Glossary

Brexit - Britain's withdrawal from the EU

CE - Crown Estate

CfD - Contract for difference

EMEC - European Marine Energy Centre

ERDF - European Regional Development Fund

ESF - European Social Fund

EU - European Union

FDI - Foreign Direct Investment

IS - Innovation system

ME - Marine energy

MEI - Marine energy industry

MEIW - Marine energy industry in Wales

MEP - Marine Energy Pembrokeshire

META - Marine Energy Testing Area

MEW - Marine Energy Wales

MLP - Multi-level Perspective

NRW - Natural Resources Wales

NUTS - Nomenclature of territorial units for statistics

ONS - Office for National Statistics

RE - Renewable energy

RETs - Renewable energy technologies

ROC - Renewable Obligation Certificate

TIS - Technological Innovation Systems

UK Government - United Kingdom Government

WEFO - Welsh European Funding

WG - Welsh Government

Chapter 1 Introduction

1.1 The transition to renewable energy

Global efforts to tackle climate change increasingly recognise the importance of decarbonising energy production (Stern et al., 2006; European Commission, 2018). It has been widely argued that incremental improvements in established energy technologies will not lead to a system that delivers the scale of change required, or adequately balance different sources, to meet global energy demand (Wagner, 2012; Frenken et al., 2007; Schaltegger and Wagner, 2011; Boons et al., 2013). Therefore, a transition to sustainable energy practices will need to be driven by continued innovation (Badi and Murtagh, 2019; Loorbach et al., 2010). These factors maintain the focus on the development trajectories of renewable energy technologies (RETs).

As a result of these potential new energy trajectories, regions around the world have been impelled to adopt a policy strategy that seeks to link regional development with addressing persistent societal challenges such as climate change (Coenen et al., 2015, Bulkeley et al., 2010). However, this outcome is offered aspired to but not realised due to the complexity of nascent technology innovation and the high-level of co-ordination demanded by the transition process (De Laurentis and Pearson, 2018; Armstrong and Bulkeley, 2014; Calvert, 2016). In relation to this study, renewable energy (RE) holds the lowest employment opportunity of all types of energy (Bryan et al., 2017) and promises can often be overstated or of short-term benefit (O'Sullivan et al., 2020). The regional context can encourage or hinder new industry development (Isaksen et al., 2018), yet the sub-national scale of government is the subject of limited analysis in pursuing sustainability goals (Van den Brande et al., 2012).

Therefore, understanding regional economic restructuring and how this can be encouraged through policy that is adapted for the region is important (Isaksen et al., 2018). Tracing the emergence of a pre-commercialisation energy innovation - the marine energy industry in

Wales (MEIW) - will allow detailed examination of the role of actors and mechanisms by which transition happens in regions, and whether economic development benefit can be drawn down to benefit those spaces. Within this research, the activities that are undertaken to advance the MEIW is regarded as an embodiment of a sustainability transition.

The marine energy industry (MEI) provides a potential source of renewable energy (RE) that could complement the capabilities of solar photovoltaic and wind energy. Globally, tidal energy resource could provide 1200 terawatt-hour per year and wave 29,500 terawatt-hour per year (European Commission, No Year). In terms of advantageous physical qualities, tidal energy is a highly predictable source of energy due to the regularity of tides. Wave energy has also been calculated to hold the highest power density of RE resources, utilising a fraction of the land area of wind power (Mossy Earth, 2020). However, the industry is pre-commercialisation and marine energy (ME) generation deployment remains at a small scale with 532 megawatts globally in 2018 (Jaganmohan, 2021a), compared to 743 gigawatts of installed wind power capacity (Jaganmohan, 2021b). This pre-commercialisation stage introduces nuances to the generalisations that can be made about sustainability transition through the evaluationof ME. Uniquely, this thesis addresses the trajectory of a technology that is navigating a path somewhere between success and failure. As such, this means that the research will consider both the spaces of innovation and transition. This will be elaborated further in Chapter 4.

ME technology development has achieved limited convergence on an acceptable design, with over one hundred conceptual and early-stage device designs globally for wave and tidal technology (Copping et al., 2014). A small number of these devices have been deployed, with tidal technology at a more advanced technology readiness level than wave energy. Complexity of design is a factor affecting technology readiness level, as tidal devices more closely resemble existing turbine technology, making it possible to capitalise on existing learning. Wave energy converters are not technically similar to other technologies and there are many more significantly different designs (Copping et al., 2014).

These technologies will be referred to collectively as ‘marine energy’ (ME) within this research.

The development of ME faces many challenges that can be considered technical (technology development, grid availability) and social (finance and markets, environmental and administrative issues) (Magagna and Uihlein, 2015). These challenges arise due to the requirement for co-ordination of technical, social, and political action to render the marine resource exploitable (Calvert, 2016), much as was required for fossil fuels (De Laurentis and Pearson, 2018). There is, however, “the assumption that energy resources are simply there to be discovered, transformed and used” (Armstrong and Bulkeley, 2014, p.66). Yet when places that have been previously overlooked for energy production become viable due to RE potential, the resource may have existing forms of use that conflict, leading to contestation of its transformation (Armstrong and Bulkeley, 2014). In this context, the natural resource under study varies in response to human action and is a dynamic phenomenon subject to re-appraisal of value (Bridge, 2009).

The varying usage of these natural resources results in spatial unevenness in their utilisation and deployment (De Laurentis and Pearson, 2018). The pre-commercialisation nature of ME, coupled with the technical and social challenges around its development, makes ME an ideal subject of study for examining the emergence of nascent technology within energy transitions, and exploring the factors that allow for regional economic benefits.

1.2 Research rational and significance

A better understanding of the mechanisms that encourage nascent technology uptake is likely to aid the expansion of RETs. Sustainability transition studies explore these factors, seeking to understand how actors and institutions engage with the socio-technical system to encourage change (Geels, 2002, 2004, 2012, 2019; Geels and Schot, 2007; Coenen et al., 2012; Rip and Kemp, 1998; Markard et al., 2012; Smith et al., 2010; Raven et al., 2012).

Solar photovoltaic and wind energy technologies have come to be integrated in the electricity system, yet despite significant resource potential ME deployment remains limited. This limited deployment, and the challenges encountered in ME development, suggest the opportunity to explore the development dynamics of a nascent technology within sustainability transition scenarios.

In order to develop RETs, attention should be paid to exploring the social and technical challenges, particularly the spatial and economic dynamics of energy transitions. ME, much like other RETs is subject to locational restrictions due to the availability and accessibility of marine resource (EMEC, 2020). The optimal conditions for energy recovery in the 'hostile' sea environment is close to shore, as grid infrastructure costs are significant (Breeze, 2019). It could be inferred that developers and supply chain companies will need to develop links to – and possibly locate around - this resource to test and deploy technology. These locational changes will have multiple impacts, both to the regions that previously focused on the hydrocarbon industry and those regions that offer the potential for new forms of energy generation (Jenniches, 2018).

If advancing energy transitions requires consideration of how they become embedded in settings, it is also vital to understand how these regions are able to best benefit from these changes. There are substantial economic potentials offered as a result of RE development that have been recognised by governments, businesses, and the third sector (Kaufmann, 2004; Kaygusuz, 2007; Watkins, 2007; OECD, 2012; Sen and Ganguly, 2017; Benedek et al., 2018; Jenniches, 2018). In understanding how regions benefit from transition there is value in understanding the motivations of regional actors in engaging with the process. In many instances, the power to hinder or promote RETs deployment rests at a regional, rather than national, scale (Jacobsson and Bergek, 2004). Yet due to a focus on the alignment of societal and technological features, until recent years transition study has been "rather silent" about issues of space and place (Boschma et al., 2017, p.36).

To understand why transition varies across locations (Köhler et al., 2019) there is merit to considering transitions as a geographically-constituted process – rather than simply as a process that affects places (Bridge et al., 2013). Through beginning to consider how the characteristics of a region influence a transition, whilst at the same time factoring in how the transition affects the region, it is possible to better understand the evolution of regional technology trajectories. This stimulates two analytical interests in this research – the dynamics of innovation-led energy transitions leading to economic development benefits, and the conditions that shape how these benefits can be realised in the regions concerned. This leads to two intersecting spaces – that of innovation and transition, that possess many inter-related processes.

The dynamic process of regional energy transition has socio-spatial dimensions that are subject to multi-scalar conditions (Chlebna and Mattes, 2020), which require some clarification. The conceptualisation of a 'region' is subject to continuing debate, sometimes signifying a devolved entity like Wales and other times a metropolitan area; yet it remains an economic, social, and environmental territorial construct (Barnes, 2011; Bristow, 2010; Paasi and Metzger, 2017).

Defined in this thesis as a space within which activities are undertaken, the region can be better conceptualised through the study of territory, scale, networks, and place (Jessop et al, 2008; Gailing et al., 2020). As such, the characteristics of a region are influenced by this spatiality, where the actors and institutions within this space have different powers of influence and control, a principal area of theorising within this research. Within these regions, there may be varying strength of institutional capacity or actors' access to resources - these factors will influence the ability to transform natural resources (Armstrong and Bulkeley, 2014; Calvert, 2016; De Laurentis and Pearson, 2018) or support innovation (Köhler et al., 2019; Esparcia, 2014). It is these divergent steering capacities that are studied within this thesis.

Those regions with a prospective marine resource advantage are presented as having an impetus for a major shift in the development trajectory of the region (Trippl and Tödtling, 2008). Yet proximity alone is not sufficient to draw down benefits – the process through which the exploitation of natural resources leads to economic advantage, and its spatial distribution, is complex (Munday et al., 2011; Hansen and Coenen, 2015), suggesting that there are many aspects aside from proximity that require interrogation. Critical questions include: what are the mechanisms needed to exploit the resource and, at the same time, use it as the basis for local economic development? And how can actors in a region utilise sustainability transition to catalyse industrial and environmental renewal? This thesis aims to address this gap, through examining how ME technology development is fostered, and how regional actors can embed the benefits of innovation and manufacturing.

There is theoretical grounding to suggest positive synergies are possible. The 'Schumpeterian' or ground-breaking new combinations of RETs and place "may provide a long-term source of competitiveness as other regions that do not share the same specialized capabilities being recombined will find it hard to copy such a success" (Boschma et al., 2017, p.2). Nevertheless, the dual challenge of fostering technology innovation *and* economic development driven by innovation requires coordination. When these challenges are put in the context of a nascent technology for which there is limited knowledge, and there are aims of a sustainability transition, it can be posited that there is a greater complexity to the range of social roles undertaken by actors in supporting the process (De Laurentis and Pearson, 2018; Armstrong and Bulkeley, 2014). Where regional ambitions are to capitalise on the economic development opportunities presented by innovation, important questions must be asked whether actors in a region can cultivate and draw down the benefits of RET development. It is therefore important to consider the likelihood of new technology innovation and regional economic development being achieved, synergistically, in the same region.

In order to benefit from these opportunities, it is necessary to establish the courses of action undertaken by regional actors – how does the support of social and technical factors such as regulatory processes and supply chain expertise contribute to the embedding of technology (Magagna and Uihlein, 2015)? This embedding will mean that regional systems configure around the technology, impacting the region and its development pathway (Raven et al., 2012; Fastenrath and Braun, 2018). However, despite availability, not all regions will seek to exploit these resources, and fewer still will seek to pull the benefits into the region, or succeed in doing so (Jenniches, 2018; Binz and Anadon, 2016). There is much that remains to be understood about why this is the case, but as yet the research on the localisation of RE source and regional capacity to support innovative technology is underexplored (Chandrashekeran, 2016).

1.3 Research framework

The framework adopted for this research draws on wider themes in transition studies. Transition study investigations of energy changes have traditionally analysed major historical shifts at a national and global scale, showing how they are often linked to broader societal changes (Smil 2005, 2010; Podobnik, 2006; Fouquet and Pearson, 1998). A low-carbon energy transition will bring about social, technological, and geographical changes that are likely to be as significant as the shift from wood to coal or the electrification of urban and rural areas (Juisto, 2009; Bridge et al., 2013). The study of RE transition is pertinent to a range of theoretical fields due to the extensive reconfigurations required in both technology and society. With a principal aim of understanding how a region comes to support ME development and deployment, transition studies literature is used as a point of departure for explaining the factors in a socio-technical system that must be mobilised for system change (Geels, 2002; Coenen et al., 2015; Boschma et al., 2017).

The literature review will consider in more detail how the Multi-level Perspective (MLP), which is a middle-level framework extensively used in transition studies, helps to understand the socio-technical configuration of mechanisms and actors that contribute to change (Geels, 2002). These mechanisms can explain the accumulation of actor activity in the context of transition through creating a space for new technology in the socio-technical regime, which is the current system (Geels, 2002). MLP theorising emphasises that change can be path dependent, where previous successful courses of action inform future action. To create space for a new technology in the socio-technical regime, market creation and disruption activities must be undertaken. These changes are facilitated by actors who seek to support industry development and the embedding of technology (Chlebna and Mattes, 2020).

This thesis will contribute to a more sophisticated understanding of regional transition processes, and the actions undertaken in an effort to embed the technology in a place. Technology embedding is hypothesised to support both innovation and economic development benefits but theorised to be complex to achieve within one region. To explore this, the research gives particular attention to whether institution type, actor agency, and regional characteristics such as the presence of other industries contribute or detract from the transition process. The incorporation of these factors in the explanatory approach draws on sustainability transition, innovation, and geography literatures.

Analytical challenges arise from the context of ME as a nascent pre-commercialisation technology in contrast with the historical focus of most transition studies (Genus and Coles, 2008). At the same time, it is important to address these challenges, to aid understanding of how regions might capture the benefits of technological change. The inevitable uncertainty of future outcomes introduces a range of complexities that are better considered using ideas from innovation literatures. The literature review fully considers the insights of these literatures in contextualising how the region and new technology innovation might impact sustainability transition. The established literatures and the research context of marine energy transition highlight gaps in knowledge that will be detailed in the research questions.

1.4 Research context

In order to explore regional influences on sustainability transition, and how economic development benefits may be drawn down by such spaces, a case study approach is adopted. The case study context is Wales, an industrial country with a long pedigree in the hydrocarbon industry, where in the 19th Century "the price of world coal was set in Cardiff" (Welsh Assembly Government, 2010). Alongside coal, gas and oil has a focal point in Milford Haven and Liverpool Bay; North Wales is home to two nuclear stations and to Dinorwig, Europe's largest pumped storage system. Where these energy technologies have previously provided secure sources of energy and high value-added employment, the coal and oil industries have undergone decline in Wales (BBC, 2014a; Merrill and Kitson, 2017; European Commission, 2020).

The RE story in Wales reflects that globally, where efforts have focused principally on fostering mature technologies like wind and solar photovoltaic. However, coastal waters around Wales hold a significant portion of the UK ME resource – a suggested one seventh of the wave energy resource, one quarter of the tidal range resource, and one third of the tidal stream resource (Crown Estate, 2012; Lewis et al., 2015). Importantly, Wales has energetic ME resource close to landfall. This suggests that there is the opportunity to pursue new energy technologies, but also a risk of dependence on existing industry and modes of economic growth. Indeed, despite the outlined advantageous starting point, the marine energy industry in Wales (MEIW) has been slow to develop. Although in 2020 there were developers located in the region, the success stories are limited due to the technology readiness level of developers and the distance from commercial grid integration of ME technology. This highlights the research gap that this thesis seeks to explore, where sustainable transition and economic development prospects are sought from a technology that cannot as yet be described as a success or a failure.

Wales as a devolved nation[1] presents an intriguing case study. It is a less-developed region with a legacy of limited innovation and entrepreneurial activity, with insufficient

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1 Hereafter referred to as a region

institutional capacity to enable change (Morgan, 2017). The Welsh Government (WG), however, has sustainable development at the core of its statutory obligations and state that where "Wales once led the world in carbon-based energy. Our goal now is to do the same for low carbon energy" (Welsh Assembly Government, 2010, p.4). This position leads to the postulation that the Welsh Government would have a vested interest in supporting innovative technology development. Together these factors make Wales a rich context in which to explore the impact of the region on sustainability transition; further offering opportunities to research these dynamics in a less-developed region. Consideration is given to the priorities that come about as a result of the region's development status. These priorities could include the necessity to draw down economic development benefits or to support technological development, with compatibilities and tensions existing between these priorities. This informs the rationale within which the research aim and questions are developed.

1.5 Research aim and questions

The research aim is to understand how regional characteristics influence sustainability energy transitions, paying particular attention to the agency of actors in less-developed regions. At the same time, the context of a nascent technology that is, globally, within the research and development phase will be considered. Is there a particular role for regional actors to support the innovation process? At the same time, are economic development benefits or sustainability transition goals at the forefront of these activities? This will be explored through three principal research questions:

RQ1. How do the characteristics of a less-developed region influence sustainability transition?

RQ2. What role do actors and institutions play in embedding technology in places, and what effect do they have on innovation?

RQ3. How do actors co-ordinate activities to pursue economic development benefits from innovation-driven sustainability transition?

Within the research context of the marine energy industry in Wales (MEIW), where Wales is a less-developed region with its own government, a range of outcomes can be postulated. It is likely that regional actors will be motivated to support innovation processes due to the economic potential these new technologies bring. Where efforts at creating new energy trajectories can be linked to regional development and growth (Coenen et al., 2015), it seems likely that the Welsh Government will support the process. This outlines a range of regional characteristics that are likely to influence the sustainability transition.

These regional actors, which includes the Welsh Government, can be conjectured to embed the technology in the region, so that a greater extent of the innovator's activities take place in situ. Yet the less-developed status of the region could introduce some limitations, meaning that exogenous actors and institutions also have a role in innovation, transition, and economic development efforts. As a result, the analysis will take place at multiple scales within that regional context. The transition mechanisms influencing change at an all-Wales scale will be considered, this will include an analysis of policies, institutions, and market mechanisms. The findings will be coupled with a comparative analysis of two subregions – within each ME is starting to emerge - to better understand how actors at the local scale seek to embed transition activities, with the aim of drawing down the benefits associated with innovation.

1.6 Thesis outline

The literature review follows this introduction and begins by defining transition mechanisms. The chapter introduces debates on how (energy) transition varies geographically and gives particular attention to how regional characteristics might influence transitions (Coenen et al., 2012). Utilising insights from innovation literature, the factors that shape these characteristics are identified as including actors, knowledge networks, clusters, and number of institutions. These factors are heterogenous and may vary in different regions, making the role of place central in a transition investigation (Hansen and Coenen, 2015). The review theorises the role of actors in influencing the transition through networks and the quality of relationships (Elzen et al., 1996). The chapter concludes by hypothesising potential causal mechanisms involving the configuration of relationships and knowledge sharing between actors in the system transition. The literature highlights that an actor may engage with a range of transition mechanisms and therefore proposes an organising framework for capturing the three main sets of processes: market creation, innovation support, and technology embedding.

Next the Methodology Chapter addresses the complexity of studying a transition that has not reached an end point. A case study approach is presented as providing the opportunity for in-depth exploration to encapsulate the wide range of factors that contribute to transition (Yin, 2013). Investigating the influence of the region on change, Wales was selected because it can provide rich evidence of the influence of a region on energy transition. The complexity of enabling system change and nascent technology innovation necessitated a multi-method approach to tease apart the causal factors. These methods included semi-structured interviews, policy evaluation, and a Q Methodology.

Chapter 4 provides an overview of the case study, detailing the social, economic, and political context of Wales. Further, the pre-commercialisation stage of ME technology will be considered in respect of its ability to contribute to conceptualisations of sustainability transition. To truly understand the transition trajectory and a region's ability to engage with these processes, this understanding is vital (O'Sullivan et al., 2020).

Turning to the analysis chapters, the Market Creation Chapter (Chapter 5) considers the conditions that support technology uptake, including policy, institutional endorsements, and grant funding. Devolution and the Welsh Government's (WG) limited consenting powers are considered against the multi-level governance background. Societal demands such as low-cost energy alongside the need to de-carbonise the energy mix are presented as creating competing demands for technology development (Bridge et al., 2013). This highlights the complex institutional environment within which technology must be developed. Financial institutions that operate at a wider spatial scale within the UK but have salience in Wales are also explored. This includes Renewable Obligation Certificates, Contracts for Difference and European Regional Development Fund (ERDF) monies.

In the next chapter (Chapter 6), the innovation support analysis considers the wide range of activities in Wales including university initiatives and EU funding. The research makes apparent that these activities are connected through knowledge sharing and transfer. Innovation literature suggests that productive relationships between actors are a pre-requisite for knowledge sharing behaviour (Inkpen & Tsang, 2005), necessitating evaluation of these relationships. Indeed, the level of knowledge sharing between supposed competitors is one of the defining features within Wales that supports technology development. However, literature considers that knowledge flow within a small group of actors is rarely sufficient to promote technology development (Uzzi, 1996; Boschma, 2005); the chapter will therefore consider how actors in Wales connect with others from outside the region. In particular, the role of Marine Energy Pembrokeshire (MEP) and Marine Energy Wales (MEW) will be considered, actors that respond both to regional development issues and the evolving marine energy industry (MEI). These actors represent the new organisational forms found during this research.

Chapter 7 considers the technology embedding characteristics that are unique to Wales and includes activities that have taken place with an aim of locking the ME transition into the region. There are several initiatives that seek to provide a distinct locale for the industry to operate within, highlighting how regional efforts can secure technology benefits in the region (Bulkeley et al., 2010). Yet in Wales, the subregions have varied outcomes and the chapter will compare the characteristics to provide better insight into the role of place in technology embedding and the drawing down of benefits.

Analysis across the market creation, innovation support, and technology embedding components is pulled together in Chapter 8, which evaluates the cumulative events, actions, and causal processes. Chapter 8 also considers whether the empirical evidence suggests that transition is taking place. A Q Methodology analysis triangulates the research findings and opinions of the industry actors. The chapter will evaluate the impact of place (region, clusters, other technology pathways), the actor relationships postulated in the literature review, and how change agents contribute to transition.

The final chapter begins by giving the key conclusions for each of the research questions. The context of transition in a less-developed region will be better characterised to understand the salience of findings to other regions. In particular, the critical role of actors and institutions within this economic development context in enabling regional embedding of a technology to support innovation will be elaborated. Detail will include how actors further co-ordinate these activities to secure economic development benefits and navigate the challenges of pre-commercialisation technology. The thesis will reflect on the wider significance of these findings, contributing to literature and theoretical development. The chapter will conclude with recommendations for future theoretical development and approaches to characterising energy transitions in less-developed regions.

Chapter 2 Literature Review

2.1 Introduction

The research aim is to understand how regional characteristics influence sustainability transition, building on a strand of innovation theory that emphasises the role of geography (Esparcia, 2014; Hansen and Coenen, 2015; Köhler et al., 2019). There has been limited attention to the role of regional characteristics within transition literature, which can include how actors interact within defined spaces, levels of prosperity, and regional institutions. This research explores how the actors and networks within the region where a new technology is developed influence the transition process.

The region – as an economic, social and environmental territorial construct (Barnes, 2011; Bristow, 2010; Paasi and Metzger, 2017) - is also likely to evolve as a result of the new technology. Transition theory suggests that wider structural changes are likely to be catalysed by the development of a transformative technology innovation in situ. The empirical focus of this thesis explores this through considering the characteristics of the region, how economic development benefits are secured, and how actors co-ordinate activities.

This literature review will proceed as follows: first the Multi-level Perspective (MLP) will be examined as the pre-eminent sustainability transition framework. Insights from the MLP will be coupled with Technological Innovation Systems (TIS) literature to better characterise the innovation system. This research will seek to extend transition thinking in two ways – through a better conceptualisation of the role of geography, and the social actions undertaken by actors to contribute to these processes. The value of investigating transition within a region and the addition of geographical concepts will first be addressed.

Then, the drivers and barriers to creating innovation will be better explored. Path dependence is highlighted by the MLP as a barrier to change, emphasising the importance of history and the spatially contingent nature of economic development that can be self-reinforcing (David, 1985, 2001; Jakobsen et al., 2012; Martin and Sunley, 2006; Martin and Simmie, 2008; Aghion et al., 2019). Path dependence is part of a decision process where previous courses of action determine the strategy that is adopted in the next instance – these can be chance events that "reverberate through history" (Martin and Sunley, 2006, p.401). New paths can, however, be created through a range of mechanisms.

The chapter then addresses how actors are an integral part of the transition process and network theory elaborates how these actors connect. It is widely contended that, where actors co-locate, clusters may form, and social capital literature considers how the quality of these relationships impacts knowledge sharing and collaboration. In turn, these co-ordinated activities may support innovation or regional economic development.

The final section of the literature review considers change agents, those actors that steer behaviour through capitalising on social capital and network relationships. In particular, this will explore the role of intermediaries who engage with technology actors, and institutional entrepreneurs who engage with deficiencies in governance or institutional practice. This culminates in a characterisation of the innovation-transition process, which provides areas of focus for the subsequent research.

2.2 Characterisation of socio-technical systems

2.2.1 Introduction

Charged with the provision of core societal functions such as energy supply, socio-technical systems can be "conceptualised as clusters of aligned elements, such as technical artefacts, knowledge, markets, regulation, cultural meaning, rules, infrastructure" (Kern, 2012, p.299). The Multi-level Perspective (MLP) specifically addresses how change occurs within such systems when technology and society co-evolve (Geels, 2012; Fastenrath and Braun, 2018). MLP theorising can encapsulate an industry's evolution with a focus on "reconstructing processes of sectoral change" (Coenen et al., 2012, p.969).

Complementing this perspective, Technological Innovation Systems (TIS) research considers the socio-technical functions that support innovation, which can be central to sustainability transitions. TIS theorising seeks to be comprehensive in its characterisation of the factors supporting an innovation system and emerging new technologies (Coenen et al., 2012). The innovation system is a political-economic concept that comprises "negotiation and learning, including exerting power, influence and trust (Isaksen and Remøe, 2001, p.300).

These literatures have been dominant in innovation and sustainability studies (Markard et al., 2012; Coenen et al., 2012) and are increasingly recognised as complementary to the clearer conceptualisation of a system transition (Meelen and Farla, 2013; Coenen and Truffer, 2012). This section of the literature review will summarise the key theoretical debates and how they contribute to the investigation of a sustainability transition.

2.2.2 The Multi-level Perspective

The multi-level perspective (MLP) is one of the central literatures for understanding sustainability transitions (Rip and Kemp, 1998; Geels, 2002, 2004; Geels and Schot, 2007; Köhler et al., 2019; Markard et al., 2012; Smith et al., 2010). Importantly, the MLP highlights the "multi-dimensional complexity of changes" (Geels, 2010, p.495) with three analytical levels (Figure 2.1). The different levels are not ontological descriptions of reality, but analytical and heuristic concepts that are designed to understand the complex dynamics of socio-technical change (Geels, 2002). Change is achieved through a non-linear process that entails co-evolution of many societal functions that are economic, socio-cultural, institutional or political (Geels, 2012; Kemp et al., 1998; Fastenrath and Braun, 2018).

MLP theorising proposes that change occurs through interacting processes between the heterogeneous niche, regime, and landscape levels (Geels, 2010). The theoretical assertion is that a technology possesses no power, but requires interaction with human agency, social structures, and organisations to fulfil attributed functions (Geels, 2002). Concomitantly, the MLP framework emphasises that technology design alone is not sufficient to ensure its uptake, requiring supportive social elements also. If a transition is to take place, actors and wider society must engage with the technology. This is evident for renewable energy technologies (RETs), as a conscious switch and restructuring of the system is required for the technology to supplant previously dominant fossil and nuclear energy sources. Take up of RETs have been demonstrably uneven to date, reflecting both social and technical factors (Kern, 2012; Cowell et al., 2017a; Cowell et al., 2017b).

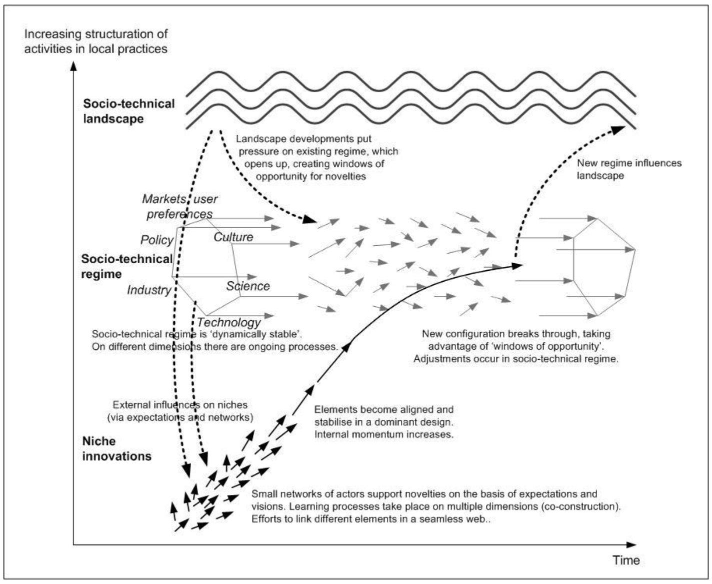


Figure 2.1. Multi-level perspective on transitions.

Source: Geels, 2011, p.28

MLP theorising outlines that incremental innovation through a series of small technology improvements occur in the regime, whereas radical innovations that supplant existing technology emanate from the niches (Geels, 2002). The niche can be viewed as a protected environment that incubates radical novelties (Schot, 1998). These new technologies have low initial technical performance and expensive start-up costs - factors that are central to the struggle of new technologies (Smith and Raven, 2012). Novelties created in the niche address problems experienced within the regime.

New technologies are initially developed within the old framework (Freeman and Perez, 1988) but provide the seeds for wider change (Geels, 2002). MLP theorising outlines a general transition dynamic where (1) momentum for the niche innovation develops (2) pressure is created through niche and landscape activity (3) the regime is destabilised and a window of opportunity is created (Geels, 2019).

The operation of niches has been characterised by analysts of Strategic Niche Management (Kemp et al., 1998; Kemp et al., 2001). Strategic Niche Management considers the creation of an environment that supports the development and early adoption of technologies. Three processes that are internal to the niche have been identified as key to its successful development: the articulation of expectations and visions by actors, the building of social networks, and learning processes across several dimensions (Elzen et al., 1996; Kemp et al., 1998).

Strategic Niche Management champions co-evolutionary approaches to ensure that the new technology matches the established socio-institutional framework (Freeman and Perez, 1988). It can be said that Strategic Niche Management utilises notions of 'up-scaling' to address technology diffusion and has therefore been criticised for promoting a linear development trajectory serviced by homogenous actors (Seiwald, 2014).

The socio-technical landscape (landscape) consists of a set of deep structural trends - heterogeneous factors that are external to technology concerns and cannot be influenced by the regime or niche (Geels, 2002). The term landscape is used to denote the image of longevity of the societal contexts, such as oil prices, economic growth, and environmental problems.

The socio-technical regime (regime) is a development of Nelson and Winter's (1982) concept of technological regimes, which explored the routine-based behaviour of engineers in the form of search heuristics. This ruleset or grammar (Rip and Kemp, 1998) contributes to the formation of technological trajectories where ways of responding to problems are "embedded in institutions and infrastructures" (Raven et al., 2012, p.67). The MLP extends this logic to encompass the activities of all within the regime, and strongly links to the concept of path dependency. Path dependence asserts that "once a particular pattern of socio-economic development is established, it can become cumulative and characterised by a high degree of persistence or 'path dependence'" (Martin and Simmie, 2008, p.185).

Path dependency is embodied in the MLP, indicated by the differential stability within the levels and thus the speed with which change occurs. A technological transition is a lengthy process and is thought to take around 50 years to complete in full (Kanger and Schot, 2016). MLP literature to date has focused on path dependency and resistance to change on the part of the regime (Geels, 2019; Meelen et al., 2019). Indeed, some of the socio-technical difficulties that are experienced by RETs stem from the way that regime components define efficiency (Geels, 2019). The stability that is created by a regime that guides technology trajectories (Geels, 2002) is theorised to require an endogenous or exogenous shock to de-lock the economy from that particular path (David, 2001). Sources of this shock include competition, industrial communities of practice, innovation, an economic crisis or other events. Another potential source of 'shock' is the creation of a new path (Garud and Karnøe, 2001), and therefore more detailed theorisation around these mechanisms would better outline how change might be achieved (Mackinnon, 2012; Essletzbichler, 2012; Simmie, 2012).

Where Geels (2010) outlines that different disciplines will approach transition from its own perspective, insights from economic geography, which shares a common understanding of path dependencies (Fastenrath and Braun, 2018), can help to analyse the embeddedness of socio-technical change in socio-spatial structures (Coenen et al., 2015; Truffer and

Coenen, 2012; Boschma et al., 2017; Truffer, 2008). These concepts will be discussed more extensively in Section 2.3.

Alongside incorporating Nelson and Winter's (1982) work, which emphasises the importance of firms, innovation, and competition, the MLP also engages with Braudel's (1982) idea of levels of time. In this context history unfolds at different rates (Raven et al., 2012) and its inclusion in the MLP reinforces path dependence principles where the landscape and regime change at a slower rate than the niche (Geels, 2002). Ontologically, utilising the MLP in the context of a transition outlines how groups of actors within the levels engage with change with more or less urgency and – potentially - agency. In paying specific attention to path creation, mechanisms that promote change can be better conceptualised.

Critically, socio-technical systems are shaped by actors and institutions (Geels and Schot, 2007). Institutions can be defined as formal and informal rules which are followed, disobeyed, or initiated (North, 1990). Institutions thereby provide planning certainty (North, 2005) and transition studies increasingly has undergone an 'institutional turn' (Fuenfschilling, 2019). The important role of institutions within socio-technical change also becomes apparent. Various socio-technical regimes may impact the transition process all at once (Binz et al., 2020). It can be inferred that the same rules must maintain multiple trajectories with competing objectives, impacting support for the new technology and posing a barrier to change.

So too are actors important within transition, including actor networks and policymakers (Truffer and Coenen, 2012). In adopting an economic geography perspective there is a focus on actors, institutions that are "central to the socio-cultural construction of the economic" (Martin, 2000, p.77), and embedded learning processes as important drivers of innovation (Bathelt et al., 2004; Fastenrath and Braun, 2018). Charged with creating "configurations that work" (Rip and Kemp, 1998, p.330), multiple social groups engage with activities in the institutional context to enact change (Geels, 2019). Transition investigations have illustrated technological and institutional co-evolution (Bathelt and Glückler, 2014; Geels, 2014; Gong and Hassink, 2019), however there is limited elaboration on the "interplay between institutions and actors" (Fuenfschilling and Truffer, 2016, p.301).

Institutions and actors are factors that are found within a particular space, and regions can then become "powerful promoters of sustainability transitions when understood as relationally embedded actors and providing crucial resources for successful innovation processes" (Truffer and Coenen, 2012, p.15). Detailing actor's agency (Smith et al., 2005; Genus and Coles, 2008) and the relationships between actors across the different ontological levels can better explain the heterogeneity of change across space (Fastenrath and Braun, 2018). The literature review returns to this issue below in 2.3, utilising network literature to understand how actors connect and social capital literature to understand the quality of these relationships. An absence of network thinking in the MLP has previously been criticised as downplaying the social element of the relationships between actors (Smith et al., 2005). However, the importance of network building and the stimulation of learning in the early phases of transition are now increasingly emphasised (Geels, 2019).

Critiques of the MLP have also emerged with respect to the characterisation of geography, where the levels are posited as scales of organisation, but do not accommodate a richer understanding of space (Bridge et al., 2013; Truffer and Coenen, 2012). Space, arguably, was previously viewed as unproblematic in many transition studies, with a focus on the national scale as the main unit of analysis (Raven et al., 2012; Smith et al., 2010). Indeed, there is sometimes an elision between the MLP's landscape as 'the global' and the niche as 'the local' where quite simply they denote different types of knowledge flow and institutional reach. As a middle-range theory (Geels, 2011) the MLP posits the global niche-regime-landscape model as the "phenomenological outlines of transitions" (Geels, 2019, p.197). Geels (2019) has contended that devising research on the 'local model' will bring about better conceptualisation of transition activities and mechanisms.

A number of the critiques levied with respect to geography and the MLP stem from researchers encountering limitations with the framework (Bridge, 2013; Raven et al., 2012). As such, there are a range of areas where the socio-spatial contextualisation of transition has been considered lacking (Binz et al., 2014; Coenen et al., 2012; Geels, 2012, Truffer et al., 2015). Questions remain around where and how transitions take place, why there are forerunner places in these shifts, and what conditions lead to change (Fastenrath and Braun, 2018). The MLP as a concept does not itself provide answers to uneven development of transitions in different spatial contexts (Fastenrath and Braun, 2018; Lawhon and Murphy, 2012).

The emerging field of geography of sustainability transitions seeks to explain such socio-spatial dynamics (Truffer et al., 2015; Coenen et al., 2012). Whilst recent work within transitions has incorporated geography, more nuanced research is needed to explain how some regions miss opportunities and others pursue them (Chandrashekeran, 2016). It is here that a theoretical perspective such as Technological Innovation Systems (TIS) can elucidate the links between society, governance, technology, and actor relationships for their contribution to innovation.

2.2.3 Technological Innovation Systems (TIS)

Introduced by Lundvall (1992) to assess and compare the functions fulfilled by actors in the innovation system, innovation system (IS) literature stems from evolutionary economic theorising (Markard and Truffer, 2008). Relationships are central to IS literature where socio-technical change is attributed to the relationships between organisations and institutions (Edquist, 2005). These insights provide complementary knowledge to the processes that drive transition.

Whilst there are different lenses to studies of IS, this research engages with Technological innovation systems (TIS) as an evaluation of a singular field (Bergek et al., 2008). TIS examination of relationships and institutions relates not only to social alignment but also technical improvement, which is evidently an important factor in achieving transition. TIS also recognises that the nature of actors, markets, institutions, or networks can obstruct and lead to the failure of a system (Carlsson and Jacobsson, 1997). To borrow from MLP-thinking, the niche is not treated as a microcosm but is integrated within the entire innovation system (Bergek et al., 2008). In this light, transition will only take place in a scenario where good technology is supported by other social elements. However, it could be argued that this overlooks the unique conditions within the niche that may be integral to successful innovation - issues discussed within Strategic Niche Management, above.

With a focus on a "network or networks of agents" (Carlsson and Stanckiewicz, 1991, p.94), the dynamism of TIS asserts the interrelated nature of processes. These networks span different locations and therefore avoid engaging in any detail with spatial aspects such as the role of the region (Binz et al. 2014; Truffer et al., 2012). The assessment of actor influences on the innovation process are central to IS (Bergek et al., 2008), and the reduced number of factors in a TIS is deemed to allow the study of what "really takes place within innovation systems" (Hekkert et al, 2007, p.418). There are stated to be four fundamental factors that combine to make a technological system - opportunity conditions, appropriability conditions, cumulation of technological knowledge, and the nature of relevant knowledge base (Malerba and Orsenigo, 1990).

Whilst an entrepreneur may catalyse a TIS (Carlsson and Stanckiewicz, 1991), it is the flow of knowledge through the system that defines it (Markard and Truffer, 2008). There is no perceived responsibility of the niche actors to push into the market or for the incumbent firms to search for solutions (Hekkert and Negro, 2009). This eliminates any perceived hierarchy of an actor automatically having a greater influence on the change process than others, focusing more on the multiple interactions that contribute to innovation. Local networks are, however, thought to be more important in the early stages of technology development (Lundvall, 1988) as they can offer "a broad range of technological competencies, the need for which is sporadic and difficult to predict (Carlsson and Stankiewicz, 1991, p.114)".

TIS also asserts the importance of alignment between institutional goals and the new technology, providing the additional insight that this is determined not only by the market but also the nature of the institutional set-up (Van de Ven, 1993; Jacobsson and Lauber, 2006). Institutional set-ups include policy, markets, and firms (Edquist, 1997). These structural components can be difficult to identify for emerging technologies, particularly "when directories are scarce [and] no industry associations exist or if the actors themselves are not aware of belonging to a certain TIS" (Bergek et al., 2008, p.12). This suggests a need to identify industry associations or relevant actors within the research to understand the contribution made to TIS change. With a distinction between the productive element of old technological systems that includes incremental innovations and the innovative element of new systems (Markard and Truffer, 2008), actors may overlap but they will not be identical.

Together, the MLP and TIS literature establish a range of insights that relate to innovation and transition mechanisms. What then is the conceptualisation of the socio-technical regime on the basis of these literatures combined? And what theoretical areas require further consideration?

2.2.4 Insights from conceptualising socio-technical systems – some intermediate conclusions

The MLP and TIS are complementary literatures to address sustainability transitions (Meelen and Farla, 2013; Coenen and Truffer, 2012; Coenen et al., 2012; Markard et al., 2012). The MLP allows for greater consideration of the social elements of a socio-technical system, grouping actors in levels that engage with change at different rates. Within these levels, MLP and Strategic Niche Management make clear the necessity for the niches to operate within a protected environment.

The MLP highlights that fundamentally, numerous elements need to coincide or be actively connected to ensure a technology's success. Within the niche, innovation support has an emphasis on the feedback loops, interactions and networks that support innovation (Kline and Rosenberg, 1986; Freeman, 1994; Freeman and Louca, 2001). These activities contribute to technological design and making the innovation attractive to the market to encourage take-up. The landscape and regime level are considered to create the conditions within the market itself to stimulate demand for the technology. Market creation relates to the stimulation of innovation and investment through policy and the enlargement of markets (Nemet, 2009). This includes creating market stability which is a feature that also greatly benefits regime technologies. Importantly, it is the alignment of developments across all levels that will determine whether a regime shift will occur (Kemp et al., 2001). This suggests a need for combined innovation support and market creation forces for a transition to take place.

Networks are at the centre of TIS literature, bringing the consideration of actors and institutions to the fore for their impact on system change. Network literature echoes TIS by highlighting the different spatial reaches of relationships. If a technology system is defined by the knowledge that flows through it, as within TIS literature (Markard and Truffer, 2008), then this would seem to infer the importance of considering knowledge flow and networks within transition. Yet MLP research confines engagement with networks to the niches, whereas the described processes bridge the posited MLP levels. TIS highlights that an investigation of transition must include consideration of actor relationships, and innovation concepts that include networks.

Critics point out that both these literatures neglect actor-oriented and agency-sensitive analysis (Farla et al., 2012). The MLP has a weak conceptualisation of social relationships between actors, and TIS "can benefit from a more explicit conceptualization of actor strategies and resources in innovation and transformation processes" (Farla et al., 2012, p.992; see also Markard and Truffer, 2008; Musiolik and Markard, 2011). This marks the potential to improve the insights of these socio-technical literatures with literatures that investigate relationships between actors.

Critically, core literatures within the MLP and TIS rarely or inadequately address how a region influences transition, with a greater focus on technology (Coenen et al., 2010; McCauley and Stephens, 2012; Truffer and Coenen, 2012). Recent theoretical advances include the work on the 'geography of sustainability transitions' which will be explored next. Similarly, the conceptualisation of 'configurational innovation systems' highlights that, for some technologies, there is a strong embedding in the local context which results in variety between locations and in spatial flexibility of innovations (Wesche et al., 2019). The relevance of including geographical factors will now be explored in more detail.

2.3 Spatial considerations in system transition

2.3.1 Introduction

The spatial dimensions of sustainability transitions were largely ignored until 2010, but subsequently have received increased attention by scholars (Truffer and Coenen, 2012; Coenen et al., 2012; Binz et al, 2014; Smith et al., 2010; Geels, 2012; Hansen and Coenen, 2015; Truffer et al., 2015; Bridge et al., 2013; Calvert et al., 2017; Chandrashekeran, 2016). Understanding why transitions occur in certain places, and their patterns in different geographical contexts thus presents a critical set of questions requiring further research. In this light, 'geography of sustainability transitions' has emerged as a strand of research (Binz et al., 2020) that concerns itself primarily with "understanding how and why transitions are similar or different across locations" (Köhler et al., 2019, p.14).

Empirical insights to date have focused on geographical unevenness, especially within urban transitions and developing countries (Binz et al., 2020; Furlong, 2014; Wieczorek, 2018). There is a need to further explore multiple geographical contexts of socio-technical change, in order to respect the "multi-scalar conception of sociotechnical trajectories" (Coenen et al., 2012, p.973). Through providing "local colour" to changes in the energy system (Bridge, 2018, p.12), it will be possible to better understand how socio-technical regions come to be embedded in particular geographical contexts (Bridge, 2018; Coenen et al., 2012).

However, devoting attention to spatial embeddedness is “not a celebration of uniqueness or variation for its own sake” but an interrogation of the distinctive characteristics that contribute to energy sector evolution (Bridge, 2018, p.14). ‘Embedding’ has previously been conceived in technological terms where preconditions are developed for further technology research. However, it is evident that exploring the “embedding of these processes in specific regional and national institutional structures” (Coenen et al., 2012, p.971) will improve the explanatory power of a transition investigation.

2.3.2 Why consider regional perspectives of transition?

Regional innovation literature suggests that “regional actors are better able to design successful policies than national actors, due to their knowledge of place specific conditions and their ability to fine-tune policies” (Hansen and Coenen, 2015, p.97). This suggests that regions are best placed to facilitate change; however, regions are more likely to transition to industries that are related to existing knowledge (Aarset and Jakobsen, 2015). These specialisations can condition the development of innovations (Köhler et al., 2019) due to the skills and capacities found within established industrial networks (Carvalho et al., 2012; Monstadt, 2007; Ornetzeder and Rohracher, 2013). Therefore, local and regional opportunities influence the development of energy practices (Nadaï and Van der Horst, 2010).

The shared conceptualisation of a region can be influenced by socio-political change or socio-technical transitions (McCauley and Murphy, 2013). The region is actively constituted by the relationships between actors, histories, and structures amongst other elements (Pierce et al., 2011). This framing is powerful within the transition context as it can be mobilised to support or impede change through a reflection of wider landscape features such as societal values, or global trends (Binz et al, 2020; Jensen et al., 2016; Murphy, 2015; Truffer et al., 2015). In this way, regional characteristics can be a dimension of path dependencies.

Processes of transition at a sub-national level have not received sufficient spatial attention (Coenen et al., 2010; McCauley and Stephens, 2012; Truffer and Coenen, 2012). This attention is important as energy transitions will reconfigure many aspects of the economy and everyday practices and may result in uneven and contested spatial developments (Bouzarovski et al., 2017; Gailing and Moss, 2016; Labussie`re et al., 2018). Regions might be "re-made" during a transition, with "reconfigured power structures, institutions, and positionalities of regime actors" (Murphy, 2015, p.83).

It could therefore be suggested "that the potential for sustainability transitions differs qualitatively between regions, and that policies ought to reflect this" (Hansen and Coenen, 2015, p.97). There is the further assertion that a varied institutional landscape allows some regions and nations to forge ahead in sustainability transition processes (Coenen et al., 2010; Loorbach and Rotmans, 2010; Späth and Rohracher, 2012; Calvert et al. 2017). This further presses the importance of understanding institutions and path dependence as an integral part of the spatial variation of transitions (Calvert et al, 2017). For researchers concerned with the interface between transition and regional economic development, how might conceptualisation of socio-technical transitions accommodate greater geographical sensitivity?

2.3.3 A regional conception of socio-technical transitions

The definitions of a 'region' can be considered an outcome of previous processes of social construction, which are continually redefined (Swyngedouw, 1997; MacKinnon, 2011). The nature and characteristics of a region are influenced by complex endogenous dynamics that include social, economic, and political aspects (Barnes, 2011; Bristow, 2010; Paasi and Metzger, 2017). In this context, research on the region sets out not to find an "essential truth about what the region 'really is', but rather (…) attempts at grappling with spatio-temporally located intellectual, political and social challenges" (Paasi and Metzger, 2017, p.21).

This matters because local context becomes an essential factor in innovation (Esparcia, 2014), and the practices in the energy transition will vary spatially due to the range of actors that engage with the RE industry (Faller, 2016). In the context of multiscalar transitions, the region therefore has a significant role in the socio-technical system (Späth and Rohracher, 2010; Mattes et al., 2015; Jehling et al., 2019). This said, the transition at a regional level incurs more risk due to interdependencies with national and international developments, alongside the aforementioned endogenous dynamics (Jehling et al., 2019). The increasing recognition of this place dependency has shifted focus on to the regional and local scale within transition research (Coenen and Truffer, 2012; Mattes et al., 2015; Truffer et al., 2015).

Work in this tradition suggests that an initiation phase for a transition creates regional transition paths where the current socio-technical configuration considers new possibilities (Strambach and Pflitsch, 2018). Actors are crucial in this phase in leading small-scale activities and building initiatives (Garud and Karnøe, 2003). Actors are unconnected with unstable interrelations (Chlebna and Mattes, 2020) and personal contacts are integral (Garud and Karnøe, 2003). Greater embedding or institutionalisation of the transition then depends on whether actors “seize the opportunity to connect and whether they are able to build steady relationships” (Chlebna and Mattes, 2020, p.69).

Research also shows that the spatial reach in the initial phases of transition is very limited and increases with technology development (Dewald and Fromhold-Eisebith, 2015; Chlebna and Mattes, 2020). Actors and technologies must prove themselves in order to form a politically supported niche (Chlebna and Mattes, 2020) that has emerging stability (Koehrsen, 2017). These processes have a regional specificity and embeddedness in multi-scalar dynamics (Chlebna and Mattes, 2020). The expansion phase that follows this initiation phase sees the institutional order start to adapt locally in the region, then expand across scales (Karnøe and Garud, 2012). The competition between new and existing technologies then increases (Chlebna and Mattes, 2020) and connections between actors intensify to exploit synergies (Garud and Karnøe, 2003).

A combination of natural resource endowment, territoriality with varying levels of institutional thickness and capacity, and the embeddedness of specific path dependencies all influence energy asset investment (Dahlmann et al., 2017). The spatial diffusion of technology is said to be "culturally contingent" (p.336) and is dependent on the embeddedness of routines (Bridge et al., 2013). The niche and regime can be thought to have different degrees of geographical embeddedness which includes sunk costs and the culture around energy technologies (Bridge et al., 2013).

The work of Chlebna and Mattes (2020) highlights the fragility of early transition phases that are highly dependent on relationship and network building, where intermediaries and stable structures are often not available or reliable (Kivimaa et al., 2019). Exploring the overlaps between the regional characteristics identified by Dahlmann et al. (2017) and the fragile network building identified by Chlebna and Mattes (2020) is a key area of interest for this research. In order to more clearly outline the potential impact of the region on a transition, it is necessary to address the key spatial lexicons that will be utilised.

2.3.4 The MLP, TIS and spatial lexicons

Spatial dimensions that might influence a transition towards low-carbon energy are location, landscape, territoriality, spatial differentiation, scaling, and spatial embeddedness (Bridge et al., 2013). This literature review addresses some of these aspects through the consideration of the region (location), territoriality, scaling, and spatial embeddedness, through paying particular attention to regional networks of actors (Chlebna and Mattes, 2020; Maskell and Malmberg, 1999; Bathelt et al., 2004; Boschma et al., 2017).

It is therefore important at this juncture to address how these spatial lexicons are defined and operationalised within this thesis. Scholars in the fields of MLP and TIS have highlighted the value of concepts such as space and scale to capture the complex dynamics of both the niches and regimes (Murphy, 2015). Research has had a stronger focus on how innovation might be a driver of change (Hansen and Coenen, 2015; Geels, 2011) but consideration should also be given to how spatiality supports the durability of incumbent systems (Cowell, 2020; Hansen and Coenen, 2015; Geels, 2011).

Research that explores spatial aspects of energy has grown rapidly (Calvert, 2016; Gailing et al., 2020), where specific examples related to the energy sector have been combined with conceptual perspectives on transitions (Bridge et al., 2013; Bridge et al., 2018). Geography of sustainability transition scholars highlight that the regional context within which socio-technical systems are embedded shape transition through the heterogeneity of actors and resources (Murphy, 2015). This has been explored predominantly through the role of cities (Bulkeley et al., 2010; Hodson and Marvin, 2010; Nevens et al., 2013) although research on the region has also been undertaken (Cooke, 2010; De Laurentis, 2012; Späth and Rohracher, 2010; Chlebna and Mattes, 2020; Mattes, 2015).

It has been suggested that there is a research void in establishing whether general concepts of spatiality need to change when engaging with the energy sector (Gailing et al., 2020). The importation of external ideas has been recognised to lead to haphazard conceptualisation (Lagendijk, 2006). Indeed, within the MLP there have been wide-ranging debates on the conceptualisation of labels such as landscape and local-global scale (Bridge et al., 2013).

There are four distinct spatial lexicons: territory, place, scale and network (Dicken et al, 2001; Paasi, 2004; Sheppard, 2002) that are argued by Jessop et al. (2008) to be utilised interchangeably. These lexicons characterise different spatial turns but are theoretically and empirically close, and should be considered as individual constituent parts rather than conflating one aspect with the entire system (Jessop et al., 2008). In doing so, the discussion of the influence of geography on a transition will be enriched (Gailing et al., 2020). Further, it is essential to consider the interdependencies of these spatial dimensions (Gailing et al., 2020).

Alongside these spatial lexicons, and in the context of an economic geography investigation of transition, a further source of debate is the concept of space. Space addresses the geographical distribution of routines, where a “combination of historical contingency and the emergence of self-reinforcing effects, steers a technology, industry or regional economy along one ‘path’ rather than another” (Martin, 2010, p.3). The articulation of ‘space’ within the MLP (Coenen et al., 2012) has been blighted with debates around scale and the influence of ‘global systems’. In some instances, the ‘global’ is credited with more power to enact change than the ‘local’, however, this forgets that global systems have a local embedding in a place which contributes to the achievement of goals (Coenen et al., 2012; Chlebna and Mattes, 2020). It can then be argued that the global scale cannot be conceptualised as superior to local or to have its own autonomous agency (Larner and Le Heron, 2002; Law, 2004). It is therefore essential not to privilege global processes of causation over the influence of local agency (Marston et al., 2005).

Economic geography conceptualises space as relational (Amin, 2002; Bathelt and Glueckler, 2003; Coenen et al., 2012; Massey, 1999). The 'distance' between actors is not measured physically and is seen as the divergence in knowledge and practices, referring to different qualities of dissimilarities (Ibert, 2010). Relational distance is measured in terms of dissimilarity with cultural norms and impacts how actors interact with one-another (Gertler, 1995). This means that 'global' networks that contain new information could be considered as distant to the 'local', which contains recirculating or 'old' knowledge. This will of course be influenced by the maturity of the network that is being considered, where geographies of niche innovation may have an important role to play.

Within this relational framing, territorial form is an area of strategy (Bridge, 2018) and is constructed through institutions and agency (Gailing et al., 2020). A territory creates inside and outside divides with bounding and control of space through political and social power (Paasi, 2008; Bridge et al., 2013). New energy spaces within existing territories require new actor networks and come as a result of rescaling energy policy (Gailing et al., 2020).

National energy laws impact local and regional communities, shaping relationships and interacting with place-making activities that compensate for RET development issues (Gailing et al., 2020). This in turn makes it possible to use RETs for potential economic development (Gailing et al., 2020). Yet the need and challenge in successfully combining innovation, organisation and territory has been long established (Storper, 1995, 1996; Dargan and Shucksmith, 2008).

Place can be viewed as the generative spatial lexicon, where territory, scale and network draw their primal sense (Casey, 2008; Gailing et al., 2020). Place is constituted as the locale and how individuals interact (Agnew, 1987). It can be conceived in respect to proximity (Gailing et al., 2020) and is the location of social practice (Miller and Ponto, 2016). To date, place has been a site of transition, rather than an "affect-laden construct" (p.81) yet it can be framed around competing visions of the future (Murphy, 2015). Actors may seek to reify places as actors, marketing it as an attractive place to live, work, and innovate (Bristow, 2010; Pike, 2011; Paasi and Metzger, 2017). This framing of place, such as a region, further adds to the affect place may have on transition. This provides a strong narrative for seeing systems of places as locations for innovation alongside the contextual support provided for incumbent energy practices (Massey, 2005; Cowell, 2020).

In thinking of how global systems must be anchored in a locale, the importance of place comes to the fore. This includes the histories and situations that shape the dynamics of planning and policy-making that seek to improve socio-economic conditions and address environmental problems (Pierce et al., 2011). Therefore, much like the region, conceptualising place as a static notion ignores that the shared understanding of place can be influenced by socio-political change or socio-technical transitions (McCauley and Murphy, 2013). Place is actively constructed by the relationships between actors, histories and structures amongst others (Pierce et al., 2011). This framing of place is powerful within the transition context as it can be mobilised to support or impede change due to the reflection of wider landscape features such as societal values, or global trends (Binz et al, 2020; Jensen et al., 2016; Murphy, 2015; Truffer et al., 2015).

A key area of deficit within transition theorising concerns the network focus of TIS, where several spatial dimensions have relevance for effective explanations. It could be argued that the connections between actors at different scales do not typically fall neatly within regional boundaries (Carlsson and Stankiewicz, 1991). A network can highlight the places that are important (Binz et al., 2014). These places may be local or distant and it is suggested that future TIS research should engage with these geographical variables (Coenen, 2015). Research suggests that socio-technical change may come through a 'system of places' to legitimise changing energy practices (Cowell, 2020). It is not enough for actors to exist within the same geographical space (Markusen, 2003), it is necessary to understand how networks are created and consolidated so that the region seizes the opportunity for transition (Chlebna and Mattes, 2020). Incorporating theoretical insight as to the complexity and reach of these networks within transition research will give insight into the intricacy of spatial relations within the niche in particular (Sengers and Raven, 2015). The structuring of these inter-relations will be further explored in the network literature in Section 2.4.

2.3.5 Operationalising geography in the study of transition in a region

What is apparent from the better conceptualisation of spatial lexicons is that there is a shared interest in the relevance of different conditions within a region and the extent of the embeddedness of the transition process. If the region is included in transition research it is possible to better account for the "context-specific forces determining the pace, scale, and direction of sociotechnical change" (Murphy, 2015, p.74).

Concepts of scale, territory, place and networks extend the investigation beyond the region whilst at the same time enriching the conceptualisation of regional dynamics (Jessop et al., 2008; Chandrashekeran 2016). Recent theorising posits socio-technical regimes as global constructs where rationalities have been extended beyond single territorial contexts (Binz et al., 2016), forming global actor networks (Miorner and Binz, 2020; Fuenfschilling and Binz, 2018; Sengers and Raven, 2015). However, through researching how the region interacts with these more spatially extensive rationalities it is possible to better understand how to support the development of niche technology.

This thesis seeks to contribute to the literature that focuses on how networks and place-specific learning processes can enable the niches (Fuenfschilling and Truffer, 2014; Geels, 2011; Hansen and Coenen, 2015). Through seeking to explain how the niche can be supported to form, and the requirements on the behalf of the regime and landscape to enable this, the niche can be contextualised against the regime practices (Chandrashekeran, 2016). Further, the reproduction of novelty can be explored through examining different spatial dimensions (Lawhon and Murphy, 2012; Murphy, 2015).

Actors within transition have individual time frames or demands (Grabher and Ibert, 2011), this framing can enrich the temporality that is outlined in the MLP. In moving beyond the temporal unfolding of a transition from actors' perspective to incorporate spatial aspects, it is possible to increase the wider observations about failure and success in transition (Faller, 2016; Coenen et al., 2012). Relevant to the research aims, Faller (2016) highlights that questions remain as to "how actors utilise their position within project arenas to influence the transition process? (p.93).

This continues to highlight the importance of the regional context, where research has been undertaken on the role of informal institutions and actor networks (O'Neill and Gibbs, 2014; Seiwald, 2014; Wirth et al., 2013), and how energy transition relates to regional or local frameworks (Mattes et al., 2015; Martin and Coenen, 2015; Negro and Hekkert, 2008). However, a focus on the practices of actors is missing from the spatial research on transition literature (Musiolik and Markard, 2011; Faller, 2016).

The foundations of the theoretical narrative is summarised in Figure 2.2, outlining the elements that have been elaborated within the MLP, TIS and spatial perspectives. The arrowed box of Figure 2.2 highlights key areas that warrant further theoretical investigation in the endeavour to be more explicit in the conceptualisation of transition in a regional context: path dependence and creation, actor relationships, and change agents.

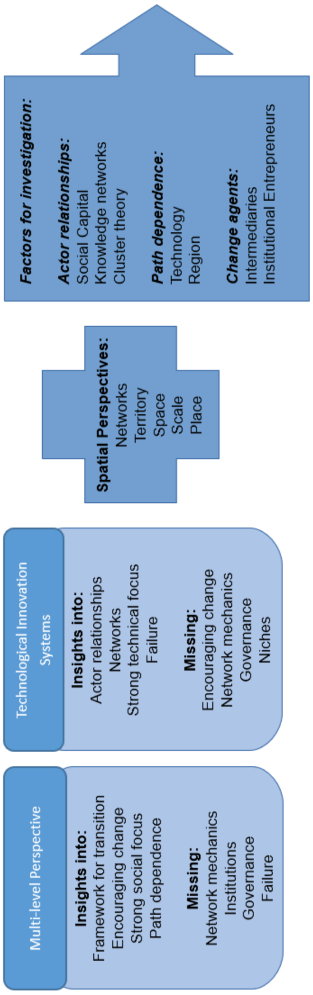


Figure 2.2. Towards spatial perspectives in transition research.

Source: Author's own,

This section has established the need to consider the influence of regional characteristics and actors on innovation and socio-technical system change. What then, are the factors that determine change or lack thereof? The literature now turns to how path dependence literature which explains adherence to a technological trajectory, and path creation explains the endogenous reconfiguration of systems.

2.4 Path dependence and creation

2.4.1 Path dependence and technology

Path dependence theory indicates that history matters and permeates socio-economic systems (Aghion et al., 2019). Path dependence does not imply historical determinism (Hakansson, 1997), but that the probable choices are contingent on preceding factors and therefore "outcomes need not be rational or optimal" (Martin and Sunley, 2002, p.401). Path dependence is useful as a concept that can both explain the persistence of current configurations and how the stimulation of new configurations come about (Vergne and Durand, 2010).

A degree of path dependence allows technical interrelatedness and compatibility to emerge between technologies. However, the sunk costs that are vested within a technology and the cost to break from this scenario are prohibitive to change (David, 1985). In energy transitions, societal systems and perceptions of how these functions should be delivered have been strongly configured around fossil-fuels (Foxon, 2011). This includes the price of energy, how infrastructure should be arranged, and how users are able to access services. Therefore, without intervention, previous decisions about technology will dictate which subsequent energy pathways emerge, including which RETs become dominant (Grubb, 1997; Clarke and Weyant, 2002). This shows how path dependency is entwined with future technological trajectories.

Another facet of path dependency are routines, which are used by agents to "economize on cognitive resources and to make up for their bounded rationality" (Cecere et al., 2014, p.1042). This, however, does not eliminate the possibility of agency (Araujo and Harrison, 2010) as reflexive actors are aware of their own position and can alter or create new paths. Indeed, this has led to the consideration of strategic agency where 'mindful deviation' from established routines takes place (Garud and Karnøe, 2001; Simmie, 2012). This deviation stems from an awareness of the current pathway and contributes to path creation.

2.4.2 Regional pathways

As “locally contingent and locally emergent” (Martin and Sunley, 2006, p.409), are some regions more prone to path dependence than others? The characteristics of a region have been found to play a role in future technology trajectories and the degree of path dependency that is experienced (Trippl et al., 2018; Njøs et al., 2020; Hassink et al., 2019). The stability that institutions provide results in incremental responses - meaning that institutional evolution typically exhibits path dependence (Martin and Sunley, 2006). These responses influence the protracted timescale at which transitions typically take place at the landscape level, remembering that multiple technology trajectories including the regime technologies must be maintained.

The government has two roles in the context of path dependence and energy technology change – shifting expectations or changing the initial conditions in order to reduce the risk associated with green technology investment (Aghion et al., 2019). These functions are carried out through governance which, as previously outlined, is particularly dependent on relationships between actors. Governments may be susceptible to over-reach or influence by vested interests (Hepburn, 2010; Aghion et al., 2019). The risk of inappropriate initial selection can contribute to governmental reticence to engage with new technology. At the same time, a stalled market will amplify the time period within which government intervention is necessary (Aghion et al., 2019).

These processes clarify how regional pathways can come to be structured around a technology but – to understand the scope for agency - there is also a need to understand how paths are created. Path creation emerges from a mobilisation of regional assets, which have been identified as natural, industrial, infrastructural, and the institutional endowment of rules, skills and knowledge (Maskell and Malmberg, 1999). These assets reflect the history of the region which can be actively “modified or reconstructed by the deliberate and purposeful action of individuals and groups within or outside the area” (Maskell and Malmberg, 1999, p.10). Path creation may include the development of links with wider extra regional networks (Binz et al., 2016) and this can play an "important role for peripheral and latecomer regions" (Mackinnon et al., 2019, p.122).

Research in economic geography has recently advocated for institutional and multi-scalar perspectives on path development and diversification processes (Boschma et al., 2017; MacKinnon et al., 2018; Hassink et al., 2019). Scholars have started to analyse the role of institutional agency in shaping industrial path creation (Grillitsch and Sotarauta, 2019; Isaksen et al., 2018; Sotarauta and Suvinen, 2018; Dawley, 2014; Njøs et al., 2020). Agency can be integral to understanding regional growth process (Rodriguez-Pose, 2013) and supporting the institutional frameworks required for new path creation (Isaksen and Jakobsen, 2017). This institutional agency embraces the idea of path creation as a process of mindful deviation not only from technological and knowledge artefacts, but also from the relevant institutional structures (Garud and Karnøe, 2001). This work has convincingly shown that distributed system building processes, drawing on policy interventions, institutional entrepreneurship, and strategic resource mobilization, play a key role for path development - largely on par with related knowledge and skill sets (Carvalho and Vale, 2018; Binz et al., 2016; Dawley, 2014; Garud et al., 2010; Garud and Karnoe, 2003).

Martin (2010) theorises three phases in new path creation. The initial preformation phase is focused on pre-existing socio-technical conditions, then the path creation phase contains experimentation and competition between actors. Finally, the path development phase has increasing local returns and agglomeration effects (Martin and Sunley, 2006) where cluster development establishes networks within a region. These phases of path creation have important echoes of transition theorising, particularly in relation to niche creation and alignment with the regime. Where the importance of place and competencies impact change, this suggests that path creation and path dependence have entwined processes (Simmie et al., 2008).

If these processes are interlinked, how previous path dependence tendencies become de-locked is important (David, 1985, 2001; Geels, 2002; Garud and Karnøe, 2001; Mackinnon, 2012; Essletzbichler, 2012; Simmie, 2012). There are five potential de-locking scenarios: indigenous path creation to exploit new technology; heterogeneity that fosters variety and ultimately innovation; transplantation of new technologies or industries; related diversification; and industrial base upgrading (Martin and Sunley, 2006). These path creating scenarios stimulated the framework advanced by Mackinnon et al. (2019) in Figure 2.3, which is sensitive to agency. The key to change is knowledgeable actors operating within multiscalar environments. Institutional entrepreneurs “put the creation into path creation” (Mackinnon et al., 2019, p.124) through coupling assets to mechanisms of path creation. Importantly, assets and actors are regionally embedded where institutions and markets are extra-regional (Mackinnon et al., 2019).

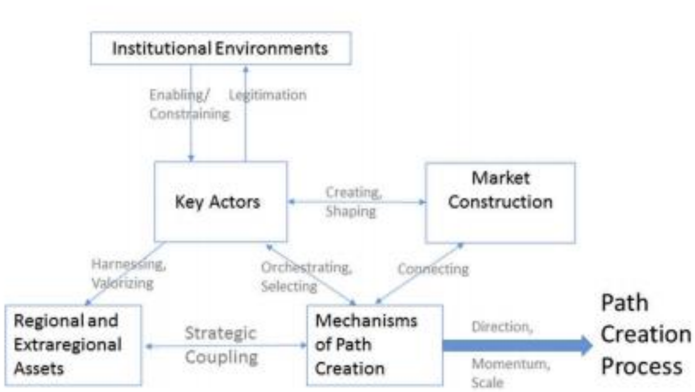


Figure 2.3. Integrative Framework for Path Creation.

Source: Mackinnon et al., 2019, p. 121

The alignment of the five mechanisms in Figure 2.3 moves the region towards path creation. In order for a new technology pathway to emerge related firms must be established, market demand must be perceptible, and access to production and knowledge factors are needed (Binz et al., 2016). This suggests the role of actors and that co-ordinated efforts rather than single actors create a new path, confirming the networked approach to change theorised thus far.

The framework has affinities with the transition mechanisms of market creation and innovation support. This is unsurprising as Mackinnon et al. (2019) sought to harness transition studies insights to understand the social and political processes aligned with emerging novelties. The relationships between the niche and regime are considered to be overlapping processes of legitimating the technology to overcome the liability of newness and anchoring, where the process then becomes aligned with the regime (Elzen et al., 2012). The legitimation of this technology requires "packs of entrepreneurs" (Mackinnon et al., 2019, p.125) working with other industry associations and agencies (Bergek et al., 2008). Institutional entrepreneurs mobilise towards legitimation by supporting the emerging regional pathway (Smith and Raven, 2012).

Further factors arise from the literature when considering the possibility of initiating path creation in a less-developed region. An organisationally thin region is typically a sparsely populated and less-developed region (Asheim and Gertler, 2005; Cooke et al., 1997) that does not benefit extensively from international knowledge flows (Trippl et al., 2018). Trippl et al. (2018) argue that these regions have a high need for exogenous actors and resources but "the lowest attractiveness and absorptive capacity" (p.699). Attractiveness reflects the capacity of a region to draw in knowledge carriers such as individuals or organisations, using local assets such as a relevant skill-base, education, security, more competitive salaries or other regional amenities. This aligns with the concept of 'the region' being marketed as an actor (Paasi and Metzger, 2017; Bristow, 2010). Absorptive capacity, in contrast, reflects the ability to anchor non-local, mobile knowledge into a locally embedded path (Crevoisier and Jeannerat, 2009). This is achieved through combining external new knowledge and prior knowledge, which includes basic skills and technological understanding - thereby influencing the ability to recognise new information for commercial application (Cohen and Levinthal, 1990).

In a less-developed region, whilst innovative firms may exist (Shearmur and Doloreux, 2016), they do not have sufficient local partners with whom to exchange knowledge (Grillitsch and Nilsson, 2015). Resourceful firms may act as 'door-openers' to external knowledge (Isaksen and Karlsen, 2013) but they require boundary-spanning and bridging capabilities (Isaksen et al., 2019). The endogenous potential for change within these regions is low due to the small number of potential sources of knowledge recombination.

These regions are often dominated by organisations that are typically traditional and resource-based industries. Investments in organisationally thin regions generally relate to natural resources, cheap labour or land (Trippl et al., 2018) that do not require embedding in the local environment (Dunning and Lundan, 2008).

This suggests a bleak prognosis for path creation in such regions, given the requirements identified by MacKinnon et al. (2019). There are, however, empirical studies that evidence that peripheral areas without a critical mass of strong actors can act as niches for experimentation (Simmie, 2012). Importantly, geographically peripheral regions may be able to utilise assets from previous pathways and this has been particularly witnessed in the offshore wind industry in the UK (Fornahl et al., 2012; Dawley et al., 2015). The empirical research will explore the concept of geographical niches for new technology creation, particularly in the context of a less-developed region. The research on the organisationally thin regions highlights that there is an intersection between the transition literatures and that of innovation systems, creating lesser or greater likelihood of path dependency.

Whilst there has been a tendency to view path creation as a regional or territorialised process (Dawley et al., 2015) there is a need to also consider the role of networks and extra-regional actors (Coe, 2011; MacKinnon, 2012; Dawley et al., 2015). Drawing on the network literature it can be suggested that the search for new technology with the aim of capitalising on existing competencies only needs a few new connections for innovation to take place (Lee and Kang, 2007). This would suggest that in these less-developed regions, social capital becomes increasingly important. Furthermore, pathway literature and the MLP highlight that shocks that change path can be endogenous or exogenous. This raises questions as to how the actors and their relationships within a less developed region influence the development of new trajectories.

2.5 Actor relationships

2.5.1 Introduction

There are emerging questions as to how connections between actors, the quality of their relationships, and how they share information influence socio-technical change. Exploration of these factors in a regional context establishes the heterogeneity of potential socio-technical system change. These complementary elements warrant explicit investigation, with insight drawn from multiple theoretical perspectives.

This section will therefore consider how networks are conceptualised in the context of place through cluster theory. Network theory will then elaborate the mechanics of the links within these clusters to address the nature of knowledge flow. Finally, social capital is used to make sense of relationship quality, where trust is an important foundation for innovation. It is also important to consider the types of actors that may engage with a change scenario, and this will feature in Section 2.5 where 'Change Agents' are discussed.

2.5.2 Cluster theory – networks in a geography

Cluster theory provides a useful means of understanding how networks of relationships function best within the context of a region. Clusters are spatial concentrations of businesses, in which collective learning is enhanced through frequent opportunities for formal and informal interactions among actors along horizontal and vertical linkages (Maskell and Malmberg, 1999; Maskell, 2001; Capello, and Faggian, 2005; Bathelt, 2005, Porter, 1990; 1998). Relationships form through informal ties among individuals (Granovetter, 1985; Uzzi 1996), interlocking affiliations among firms (Mizruchi 1992), or formal strategic alliances (Eisenhardt and Schoonhoven, 1996; Powell et al., 1996).

The connections between nodes (firms or individuals) in clusters has been conceptualised as the "plumbing" of markets with 'pipelines' through which knowledge flows (White, 1981; Powell et al., 1990; Burt, 1992; Podolny, 2001; Owen-Smith and Powell, 2004). Successful clusters build on these 'pipelines' to maintain various low-cost channels of knowledge. Due to transaction costs each firm is only able to support a limited number of external linkages as each link requires resources to establish and maintain (Grabher, 2001). It is therefore essential to consider the value of each type of link and the way in which the relationship is maintained. In this context the membership of networks and the engagement of intermediaries can play a significant role.

Global channels contribute to a cluster's cohesion and translation of information between actors (Murdoch, 1995), but there is a bias towards filtering out 'failed' information. The local 'buzz' of neighbouring firms allows efficient knowledge gains that perhaps include discussion of failure. In nascent technology development, understanding the pitfalls experienced by other agents could shorten the innovation process - a likely route to success. However, familiarity with other nodes' knowledge leads to lock-in (Uzzi 1996; Boschma, 2005), so linkages with external actors must also be maintained (Bathelt et al., 2004).

Research has shown that a successful cluster has a less dense network that involves global channels of information (Bathelt et al., 2004; Owen-Smith and Powell, 2004). It has been argued that as the knowledge becomes more codified, proximity to other nodes plays a lesser role, but costs are still incurred in its accumulation and application (Bathelt et al., 2004). Further, this reiterates the economic geography assertion that space can be relational (Amin, 2002; Bathelt and Glueckler, 2003; Coenen et al., 2012; Massey et al., 1999). This highlights how an effective combination of global knowledge, combined with local knowledge, can accelerate technology development.

There is a delicate balance between sufficient 'outside' information and a firm remaining invested in the cluster. It is in this context that knowledge gatekeepers who act as a finding and translation unit have a significant role to play in diffusing knowledge within the cluster (Giuliani and Bell, 2005; Morrison, 2008; Graf, 2011). This emphasises the relevance of intermediaries as agents who connect organisations to collaborate and share knowledge.

However, the transition intermediary literature will show that the role of these agents in a transition context has not been fully considered (Kivimaa et al., 2019).

Cluster theory shows that when a technology becomes increasingly embedded in a region, structures are introduced that facilitate knowledge flow which can in turn support technology transition. In turn, the social structure of the region evolves as a result of the technology (Geels, 2012; Fastenrath and Braun, 2018). Outcomes in this scenario may be that the region is an increasingly attractive location to other potential technology developers. Path dependence literature also highlights that the higher the number of actors in the region, the greater potential there is for knowledge recombination (Trippl et al., 2018).

However, within a cluster the impact of knowledge sharing is limited by the strength of ties within the cluster. Certain types of knowledge can lead to a competitive advantage, so sharing this knowledge then presents a real cost to the firm (Cassi and Zirulia, 2008). Indeed, firms with similar products have little reason to cooperate but their co-location allows them to observe and compare themselves with their competitors (Porter, 1990; 1998).

Cluster theory does suggest however that in the context of transition, actors are right to invest in developing social relationships with ‘neighbours’. In order to achieve a wider societal transition through supporting innovation, it is also important to maintain relationships with firms and actors elsewhere. Whilst cluster theory tells much of the importance of links between firms to achieve success and innovation, without the contextualisation of the network and social capital literature there is little insight into how these relationships can be achieved that are dependent upon a certain critical mass of businesses.

2.5.3 Network theory – the structure of relationships

Network research is applied to a range of outcomes such as the likelihood of getting a job (Granovetter, 1973), being promoted (Brass, 1984, 1985; Burt, 1992), or being creative (Burt, 2004, Perry-Smith, 2006). Traditionally network studies are empirical, relating features of a network to an outcome. This section will explore network literature and system transition; firstly, to contemplate how actors in the niches or region may mobilise social capital to promote a desired outcome; secondly, to gain better understanding of how the relationships between actors throughout the socio-technical system might allow knowledge to flow.

A network's function is to support the flow or distribution of information. Network literature such as Granovetter's (1973) 'strength of weak ties' and Burt's (1992) 'structural holes' emphasise the need for gaps in the network structure to allow the opportunity for new knowledge and the potential of innovation. Particularly relevant to the conceptualisation of a niche is the small-world network where there are dense clusters of interaction connected by weak bridging ties (Fleming et al., 2007) that come as a result of social worlds overlapping (Granovetter, 1973). Small-world networks are considered to enhance innovative creativity as dense local clusters can coexist with distant and diverse relationships (Lee and Kang, 2007). This network structure highlights geographical lenses of local networks within the innovation context. Further, it overlaps with the conclusions of cluster theorists as to the value of local networks connected to outside knowledge (Bathelt et al. 2004; Owen-Smith and Powell 2004).

The network literature further consolidates the importance of clusters within a regional context - how actors are connected in a locality will impact how knowledge is shared. It also suggests how those niche firms that locate due to natural resource endowment or as a result of technological history might benefit from embedding in the region. The literature also suggests that it is pertinent for the niche technology actor to develop relationships with regional and extra-regional actors, through the fostering of social capital.

2.5.4 Social capital – the quality of relationships

Social capital theory has been operationalised by a range of scholars (Payne et al., 2011) and addresses how the social organisation of networks, norms and social trust facilitate co-ordination for mutually beneficially outcomes (Putnam, 1995). These shared values and understandings foster trust between individuals and groups, allowing them to work together (OECD.org, no year). When these attributes are related to organisational behaviour, insight is gained as to how knowledge can be accessed both within and across organisations (Nahapiet and Ghoshal, 1998; Tsai and Ghoshal, 1998; Gargiulo and Benassi, 2000; Tsai, 2000; Inkpen and Tsang, 2005). Related to geography, social capital is deemed to support regional development through, inter alia, creating an enabling structure for entrepreneurs (Westlund and Bolton, 2003).

The type of social capital within a network is conventionally ordered along three dimensions of structural, cognitive, or relational influences (Nahapiet and Goshal, 1998) and value is added to the study of network social processes (Lee, Lee and Pennings, 2001). The structural dimension of social capital reflects much of the theorising of network literatures, highlighting how actors connect and the value in doing so. Cognitive dimensions emphasise that organisations need a shared outlook in order to be able to communicate information. These shared stances can represent a source of competitive advantage and consist of shared goals, vision, or culture (Inkpen and Tsang, 2005; Tsai and Ghoshal, 1998). Personal relationships that develop over time are considered in the relational dimension (Nahapiet and Ghoshal, 1998), where concepts of trust are found. Trust fostered through social capital is "one of the most researched and critical factors affecting knowledge sharing and transfer" (Lefebvre et al., 2016, p.571; see also: Inkpen and Tsang, 2005; Lee, 2009).

These dimensions would suggest that mobilising social capital has the ability to influence transition through supporting the innovation processes and navigating the risks during testing and up-scaling. Governance literature emphasises the importance of 'guiding visions' (Rotmans and Kemp, 2001; Berkhout et al., 2004), even where desired endpoints are contested (Smith et al., 2005). This reflects the cognitive dimensions of social capital where shared goals are paramount (Inkpen and Tsang, 2005; Tsai and Ghoshal, 1998). These visions act as a heuristic in defining the problems and creating plausible alternatives or 'possibility space' (Smith et al., 2005, p.1506). This suggests that the fostering of social capital is an integral function to market creation where governments can stimulate demand for a technology. Noting that socio-technical agents are varied, potential agents include technology developers, supply chain organisations, public research bodies, policymakers and other institutions.

The costs associated with the management of relationships are known as transaction costs (Coase, 1937; Williamson, 1975). Transaction costs are significant in the absence of social capital, where trust is replaced by formal rules that must be negotiated and agreed upon (Fukuyama, 1995). Trust has been shown to provide competitive advantage (Fukuyama, 1995), economic growth (Knack and Keefer, 1997) and positively influence investment (Zak and Knack, 2001). Therefore, focusing on the development of social capital may generate an opportunity for niche organisations to progress, with reduced transaction costs, but at the same time requires resource investment in its generation.

Within a transition, governance requires co-operation between multiple actors to drive change. Transaction costs rise as more parties are enlisted to negotiate a solution and may reach a point that they become prohibitive (Scharpf, 1997). In a situation where multilevel governance is integral to the environmental governance field (Bulkeley et al., 2003; Boyle, 2002; Cowell, 2003; Fairbrass and Jordan, 2001) and institutions are extra regional (Mackinnon et al., 2019), there is the possibility that the fostering of social capital will not be wholly localised. Therefore, the empirical research should consider actions undertaken to minimise transaction costs and the reach of social networks.

2.5.5 Actor relationships – some conclusions

The iterative connections between social capital, networks, and clusters to facilitate knowledge flow and influence transition is apparent across a number of literatures.

Cognitive compatibilities between the developers and governance actors provide the potential to foster the shared visions that are considered integral to change. Clusters and networks present the opportunity to foster trust, which is considered critical to knowledge sharing, providing an opportunity for economic growth. This reduces transaction costs which can be significant in governance and knowledge acquisition processes. Network literature also makes apparent that how and why these actors engage with networks can influence the type of knowledge that is shared and the activities that are undertaken. Furthermore, transaction costs can inhibit the number of relationships with which an actor can engage in a network, sometimes necessitating intermediaries to optimise connections. What then is the role of intermediary actors within networks in shaping a transition or encouraging the drawdown of economic development benefits?

2.6 Change agents that contribute to transition

The actor relationships literature has highlighted the intricacy of establishing and maintaining networks, and the socio-technical literature has highlighted the importance of these networks in achieving transition. The transaction costs are significant for technology and governance actors to maintain good quality relationships, creating demand for intermediaries to undertake a facilitation role. Furthermore, in the context of transition where institutions need to co-evolve with industrial change, institutional entrepreneurs may encourage industry and institution alignment.

2.6.1 Intermediaries

Intermediaries can be a range of actors including firms (Stankiewicz, 1995), individuals (Allen, 2003), a programme of work (Iles and Yolles, 2002), or a network (van Lente et al., 2003). Intermediaries are dynamic and co-ordinate activities in multiple domains (Miller, 2001; Moss, 2009). The roles undertaken by intermediaries include facilitating, configuring, brokering, and enabling pre-domestication of innovative technologies. This pre-domestication is important, where transition literature highlights that frequently the technologies designed in the niches often mismatch with the structure of the regime, requiring mediation for better alignment (Freeman and Perez, 1988; Geels, 2002).

The multiple changing facets of a transition emphasises the need for intermediary action to mediate the alignment of technology and society (van Lente et al., 2003; Geels and Deuten, 2006; Moss, 2009; Kivimaa et al., 2019). Furthermore, intermediary actors are viewed as key catalysts that accelerate system transition (Hodson et al., 2013; Kivimaa et al., 2019) if they are a part of a transition policy (Wieczorek and Hekkert, 2012). This highlights the importance of social capital and governance actor buy-in to drive socio-technical change.

Literature considering transition intermediaries is recent and limited (Hodson and Marvin, 2009; Moss, 2009; Guy et al., 2011), although a lack of consensus on the activities that should be focused upon “has hindered communication of the concept” (Kivimaa et al., 2019, p.1063). An initial typology of transition intermediaries has been developed by Kivimaa et al. (2019). The study performed a systematic literature review that found MLP and Strategic Niche Management thinking to be more dominant than that of TIS when conceptualising transition intermediaries. Characterised by four conceptual lenses, transition intermediaries are typically systemic intermediaries, innovation intermediaries, and those that engage with urban or niche development.

The typology developed by Kivimaa et al. (2019) utilises the structure of the MLP and highlights the goals and normative positions that are adopted by intermediaries. These characteristics are important as no one actor has sufficient resources to control a regime and actors are therefore dependent on one-another for resources (Smith et al., 2005).

Intermediaries are likely to evolve as a result of new socio-technical configurations, with niche intermediaries connecting multiple local projects and promoting the diffusion of knowledge (Kivimaa et al., 2019). Alongside this new conceptualisation of niche intermediaries, the established theory on innovation intermediaries outlines engagement with the unpredictability of technological change. Innovation intermediaries contribute to market organisation, intervening in the absence of existing linkages between potential users and suppliers that are needed for innovation to be sustained (Stewart and Hyysalo, 2008). These innovation intermediaries create opportunities for the development of emerging technologies and can be identified by their activities in gathering, developing and disseminating knowledge (Stewart and Hyysalo, 2008).

When evaluating intermediaries, it is important to consider what and whose interests do they promote (Moss, 2009). There are multiple possible motivations that include a transition to an environmentally comprehensive solution, or the promotion of a particular technology in order to secure business success. Whilst it is often assumed that intermediaries are neutral, many intermediaries take the form of consultancy groups making a profit from the role. These are amongst the most studied type of intermediary (Bessant and Rush, 1995; Howells, 2006). The need for intermediaries stems from the asymmetry of information that is possessed by actors in an industry or network. Whilst it has been concluded that this asymmetry can contribute to long-run cluster success, many individual firms utilise intermediaries to aid the discovery of desired information.

Much like firms and networks, intermediaries are limited by the connections with the market, and the amount of information that can be accumulated (Stewart and Hyysalo, 2008). Furthermore, intermediaries may not play a separate functional role, but engage with a range of activities that contribute to the innovation process (Howells, 2006). Alongside absorptive capacity and transaction cost limitations, there can be a danger of intermediaries making themselves obligatory points of passage to connect with others (Latour, 1987). This could be as part of their business model (Burt, 2004) or to provide a strong bargaining position for trade association or user group members (Stewart and Hyysalo, 2008). Such gatekeeping activity could be a particular stumbling block in a nascent industry where it can be difficult to connect directly with the supply chain or other relevant actors.

These insights suggest that intermediaries can be viewed predominantly as a business function, with a role to co-ordinate activities between other business actors. In respect of a transition, intermediaries may help overcome path dependency by strengthening social capital and recognising network structure weaknesses. Alongside intermediaries, institutional entrepreneurs are actors that engage with change, and their role in engaging with institutional deficiencies will now be considered.

2.6.2 Institutional Entrepreneurship

The central question to studying institutional entrepreneurship is considered to be "if our norms and collective beliefs are institutionally determined, how can human agency be a factor in institutional change?" (Battilana et al., 2009, p.67). This acknowledges that the ability to change is also limited by the same institutions that actors wish to change (Battilana, 2006; Leca and Naccache, 2006; Seo and Creed, 2002). This asserts the path dependency that is generated by institutions, and the difficulty that can be experienced in breaking free.

As highlighted in the transition literature, agents within a change scenario can include institutions. Institutions are deeply engrained aspects of social structure that constrain behaviour (North, 1991, 2005; Scott, 2005), becoming a 'taken for granted' rule that acts as an implicit guideline (Powell and DiMaggio, 1991). The relationship between innovation and institutions is underdeveloped (Hoogstraaten et al., 2020) with a small number of studies that explore the co-evolution of innovation and institution (Fuenfschilling and Truffer, 2016; Kukk et al., 2016; Pelzer et al., 2019; Smink et al., 2015; Sotarauta and Pulkkinen, 2011). However, based on the transition literature, consideration of this co-evolution is important to system change.

Institutional entrepreneurship occurs where actors "innovate organizationally against the logics of their own national innovation systems" (Hung and Whittington, 2011. p.526). As a result, institutional entrepreneurs can be a form of actor or a type of activity that has underpinnings of entrepreneurship to create new institutions. A need to innovate against the current innovation system logic arises in the relatively recent evolution of green growth goals - institutions must support both environmental and growth aims.

These new ways of working suggest experimentation on the part of governmental bodies and the establishment of new institutions that promote learning and network development. At the same time, these government actors may be required to maintain incumbent technologies also, suggesting divergent roles in maintaining multiple technology trajectories. Therefore, in order to support innovation diffusion and uptake, “institutional change is pivotal” (Hoogstraaten et al., 2020, p.114).

In this complex institutional scenario, it is likely that there are issues with the ‘implicit guidelines’ that are established. In this respect, institutional entrepreneurship research aims to understand how social actors work around an innovation system through strategising and mobilising assets for institutional change (Garud et al., 2007).

The Policy Streams Approach (Kingdon, 1984, 1995) perhaps highlights how some issues come to be overlooked, where actors then must intervene. The problem stream within the Policy Streams Approach (Kingdon, 1984, 1995) shows that from a long list of public matters, only a few will be given attention by decision makers. The policy stream then considers these problems and proposes alternative solutions, much like the visions that guide the transition niche. At the same time, the political stream relates these problems and solutions to political issues such as election results and changes of administration. Each of these three streams develop independently, but when aspects of each stream align there is an opportunity for change, or a policy window (Guldbrandsson and Fossum, 2009). This explains why it may be necessary to undertaken action that draws attention to the problem and the potential solution (Kingdon, 1995). These actors are known as policy entrepreneurs (Guldbrandsson and Fossum, 2009) and work within the world of politics and policymaking (Petridou and Mintrom, 2020).

Much like these policy entrepreneurs, institutional entrepreneurs seek to address deficiencies in the institutional framework and social conditions that might facilitate the take-up of a new initiative. Institutions more broadly address formal and informal arrangements (North, 1990). The study of institutional entrepreneurs is therefore an entry point to institutional theorising in system transition (Hoogstraaten et al., 2020), echoing how actors contribute to the development of the niche in Strategic Niche Management theorising (Kemp et al., 1998; Kemp et al., 2001; Hoogma, 2000). In this way, institutional changes that would facilitate scale-up can be promoted. The development of the niche is prompted by the articulation of visions (Elzen et al., 1996) and the building of social networks. These activities create a new system that ties "the functioning of disparate sets of institutions together" (Garud et al., 2002, p.196), providing insight into agency and institutionalisation as an on-going multi-actor process (Washington and Ventresca, 2004; Sotarauta and Mustikkamäki, 2015).

It is therefore important to study institutional entrepreneurship within a transition as innovators must often engage with existing expectations and focus on establishing the degree of institutional change required (Holloway, 2015; Salvetti and O'Toole, 2017). The literatures on institutional entrepreneurship are well aligned with MLP and TIS (Hoogstraaten et al., 2020) through the study of how actors can contribute to institutional change (Hekkert et al., 2007; Bergek et al., 2008). Further, there are well developed frameworks that allow for comparative studies (Hoogstraaten et al., 2020; Tracey et al. 2011).

Part of the institionalisation process requires actors to defend the emergence of the new institution (d'Ovidio and Pradel, 2012). The actors, who may be groups or individuals (Battilana et al., 2009), must have sufficient resources and see an opportunity to achieve a goal that they value highly (DiMaggio, 1988). This aligns with transition and social capital principles of a common vision (Elzen et al., 1996; Kemp et al., 1998; Inkpen and Tsang, 2005). To an institutional entrepreneur, social capital is a resource much like financial capacity (Hoogstraaten et al., 2020). In the absence of sufficient market creation efforts, innovation support actors may be driven to self-organise in order to promote the change their technology requires. This activity can take place in multiple contexts, examples include lobbying to change energy tariffs in the UK (Toke, 2007) and the differentiation of

Renewable Obligation Certificate levels on the part of the Scottish Government (Jeffrey et al., 2013; Winskel et al., 2009). The extent to which institutional entrepreneurship on behalf of the niche can destabilise the socio-technical regime will be explored empirically.

Institutional entrepreneurs are not agents that are disembedded (Battilana et al., 2009) or heroes of change (Meyer, 2006). Whilst institutional entrepreneurship is often an unplanned, personal form of agency (Ritvala and Kleymann, 2012), an actor needs expertise to not only make sense of the process but also influence its direction. Empirical research suggests that these actors often lack sufficient independent resources (Fligstein and Mara-Drita, 1996; Garud et al., 2002) and gain the support of other actors through mobilising institutional logics that match that of allies. This further asserts the requirement of self-organising networks in order to promote institutional change, echoing the transition and social capital literature.

Agency is employed in different contexts to achieve the desired outcome, achieving change through three principal forms: leveraging, accumulating, and convening (Dorado, 2005). Leveraging begins with a defined project, support is then gained from subsidiary backers and actors that have a stake in the field affected. These actors are politically skilled and their talents at framing (Rao, 1998) and convincing others of the need for change are crucial for this process to succeed (Dorado, 2005). The principles of accumulating argue that a web of independent actions and interactions bring about change, and that the origin of new industries cannot be traced back to a few entrepreneurs (Dorado, 2005). In contrast to leveraging that focuses on a project, convening suggests that institutional change requires interorganisational arrangements to initiate the process of change. Activities are undertaken to persuade others of the viability of collaborating to devise a solution to a problem (Brown and Ashman, 1996). The three forms of agency are not independent, but one will dominate (Dorado, 2005). These forms of agency highlight the two areas of focus of change: the technology, or the institutional context into which the technology is inserted. This suggests that an institutional entrepreneur may mobilise market creation and innovation support mechanisms in order to promote change.

The institutional entrepreneurship literature highlights that actors can engage with institutions in order to achieve change (Battilana et al., 2012). These perspectives have the potential to benefit MLP and TIS theorising due to the overlap in system change principles and institutionalisation of routines (Hoogstraaten et al., 2020). However, institutional entrepreneurship literature has had limited impact on transition studies, most likely due to the divergent intellectual origins (Hoogstraaten et al., 2020). Where institutional change is only part of the transition process (Hoogstraaten et al., 2020), its study will benefit the better conceptualisation of change. Indeed, the social position of institutional entrepreneurs and other actors warrants consideration, where this may change when engaging in a range of activities (Pelzer et al., 2019). Importantly, high-status and low-status actors can create change, where low-status actors' peripheral position aligns with the notion of the regime (Hoogstraaten et al., 2020). It is therefore vital to investigate how the affiliations between different types of actor and networked agents impact sustainable change.

2.6.3 Key agents for transition – conclusions

This section has highlighted two of the main types of agent that can engage with path dependency in a socio-technical system to promote change. Intermediaries work to pre-domesticate a technology to ensure integration into the market. Those that undertake institutional entrepreneurship seek to innovate against the current system.

Whilst some of the activities these actors undertake are similar, different system change mechanisms are employed. Intermediaries could be viewed as innovation support actors due to primary engagement with actors that create technology in order to strengthen network processes. Institutional entrepreneurs particularly engage with the rules within the system, seeking to change them to best benefit the technology to create the space in the market for the innovation. The activities of institutional entrepreneurs echo Strategic Niche Management literature where the need to articulate visions and build social networks is a core activity. Furthermore, it must be asked how this might contribute to embedding a technology in a region as steps are undertaken to co-evolve the technology and institutional system.

This final section of the literature review can be viewed as further validation for the inclusion of geography within sustainability transition studies. The empirical research must be attuned to the activities of the range of actors that constitute the socio-technical system, their distribution and reach. In order to effectively analyse how actors seek to support change through leveraging social capital, the next section will undertake preliminary theorising of the research questions and hypothesise likely relationships and knowledge flow between actors within a region.

2.7 Conceptual framework development and conclusions

2.7.1 Overview

This literature review forms the scaffolding for the development of a conceptual framework, although "a good framework should not be regarded as a rigid structure, but as a valuable guide to empirical research" (Walsham, 1993, p.71). In response to the challenge posed by the social science study of transition, the literature review utilises a wide range of theoretical perspectives to detail some of the social, technical, and economic elements that influence socio-technical change. The complex nature of a system transition means that there remain theoretical challenges, especially how actors influence the change process and the impact of the region. This section will hypothesise the likely relationship between these theoretical arguments and the research questions.

Thus far, the combined insight of MLP and TIS literatures highlight that actors, relationships, networks, and institutions warrant attention in a transition analysis. Network literature details how networks of actors will be influential in facilitating innovation and guiding industry change. It is likely that intermediaries will be brought in to support network functions.

The MLP posits path dependency within institutions as an inhibiting concept that explains the generally slow rate with which change happens. Institutions are the rules that are integral to a society, and it can be concluded that their evolution will be essential for change to be achieved. Actors may engage with these institutions to reinforce or alter the development pathway. In the absence of a high number of appropriate institutions or poor fit with the transition, institutional entrepreneurs may emerge to bolster these deficiencies. Further in response to these constraints, Strategic Niche Management and MLP literature advocate the creation of a niche with a protected environment where new technologies and networks can evolve. Niche actors may then mobilise to exert pressure on incumbent processes and support the development of radical innovation. TIS highlights that actors may not be aware of their ability to contribute to a new technology, with a potential role for bridging actors to foster new network creation.

Innovation literature considers the role of a region through the creation of co-located clusters, but existing transition frameworks have paid much less attention to how spatial dimensions shape the transition process. Extant economic geography literatures address the roles of actors and networks in contributing to these different regional technology trajectories. The literature summarised in this chapter will be explored throughout this thesis with the preliminary hypotheses in response to the research questions outlined in this section.

2.7.2 Research question 1 theorising

> RQ1: How do the characteristics of a less-developed region influence sustainability transition?

The research aim is to explore the impact of a region on the transition process, paying particular attention to the characteristics of the region and the nature of the actors present for their impact on technological change. These are aspects that are currently underdeveloped in transition research and there are emerging questions as to how transition takes effect in a region. It can be hypothesised that on the one hand there may be interesting new opportunities for technology development, but on the other, there are problems of path dependency, lock-in and institutional thinness particularly in less developed contexts. The likely presence of these aspects in the case study can be surmised from the pre-commercialisation nature of the MEI and the less-developed status of the region. This research question therefore seeks to explore and hypothesise the geography of sustainability transition in the context of a less-developed region, understanding that the characteristics of the region within which a nascent technology is developed impacts the outcome.

The literature review leads to the principal hypothesis that the actors from within, rather than outside, the region will have the most significant impact. In particular, the literature that highlights that less developed or peripheral regions will have a low number of actors, potentially limiting the possibility of innovation (Trippl et al., 2018). It can therefore be hypothesised that the relationships between these actors will play a fundamental role in system transition and innovation enablement due to the importance of local networks in the early phases of innovation (Lundvall, 1988). There is also a risk that a less-developed region with a low number of actors may be unattractive for innovators to locate within, reflecting the extensive literature that highlights the poor prognosis for innovation (Trippl et al., 2018).

It could therefore be suggested that there are potentially significant barriers to the ability of regional and governmental actors sell the region to innovators. Further, based on the observation that environmental governance requires multi-scalar political engagement, it seems likely that government bodies would collaborate with the industry to facilitate innovation and transition. Figure 2.4 is the first step in conceptual framework development, conjecturing the likely relationships between regional actors driving towards system transition.

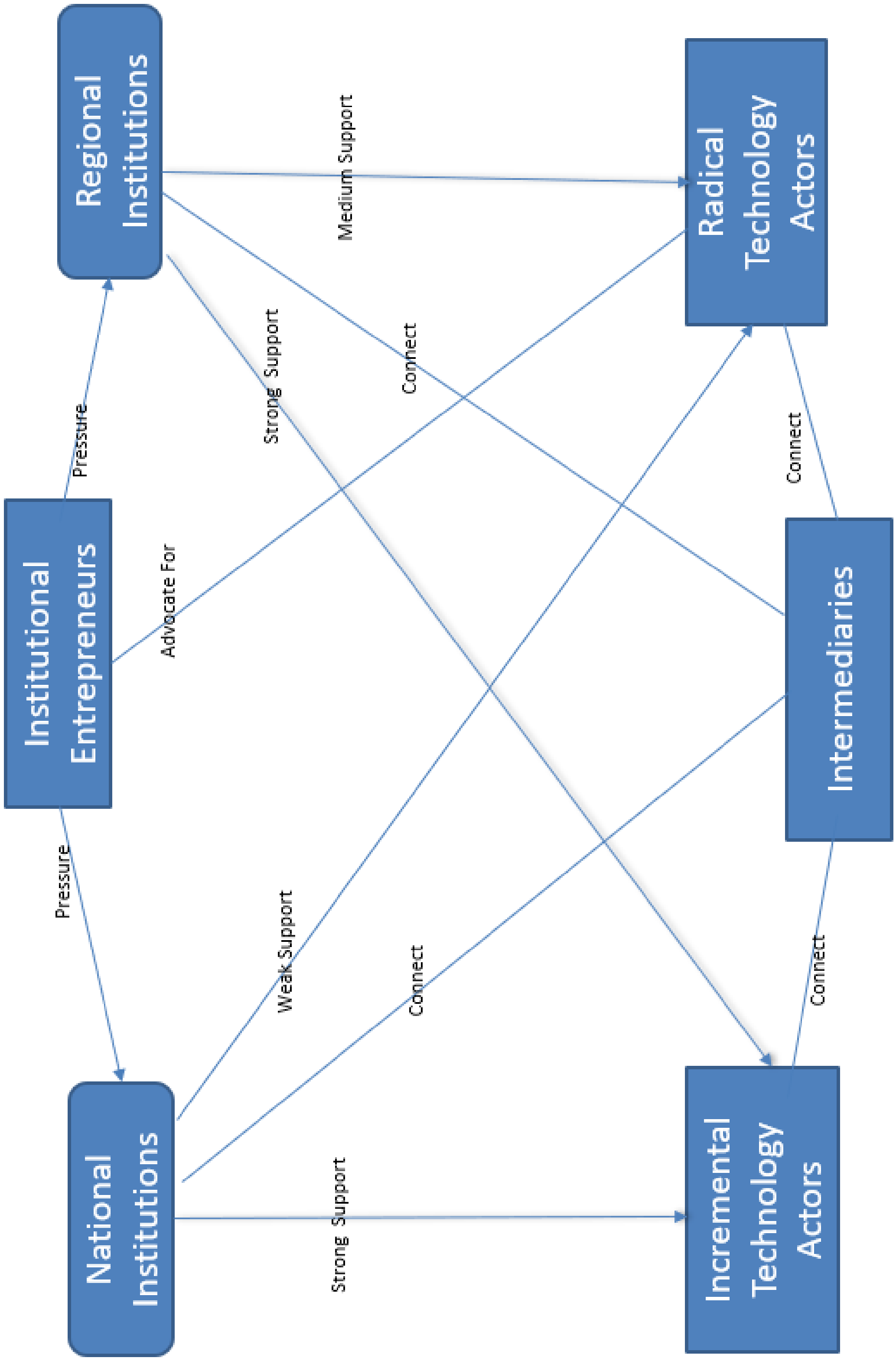


Figure 2.4. Regional relationships to drive transition.

Source: Author's own

Figure 2.4 seeks to postulate a prospective regional innovation context where the agency of regional actors will result in the development of a network of relationships between different actors where social capital will be used to work towards various goals and outcomes. It can be theorised that the relationships will have different qualities – trust will be higher in some relationships and others will simply be bridging ties between different organisations. In this way this framework goes beyond simply speculating the strength of the relationships to note how they will be qualitatively different.

Alongside this, the framework captures the theorising as to how actors might simultaneously exert influence and support the activities of others. Literature advances the notion that these relationships are bound with social capital where shared goals mobilise actors and enable collaborative work. Network literature establishes how these actors connect and the need to combine dense local connections with ties to outside organisations through which new knowledge can flow. The development of relational social capital is an important spatial perspective, trust is fostered in the local environment facilitating the sharing of knowledge. This raises questions as to how social capital within regional firm networks promotes knowledge networking.

The exploration of this research question will ask how relationships between regional actors shape a transition pathway, extending principles outlined in cluster literature to combine network theorising with the importance of the region. Knowledge spillovers could be considered highly desirable to a less-developed region; do regional actors therefore seek out such opportunities? As a result, governance and the multiple trajectories these institutions might maintain should be evaluated. It can be postulated that activities in these areas will add strength to the potential for a peripheral or less-developed region to act as a niche (Simmie, 2012).

Figure 2.4 outlines the nexus of innovation and transition spaces, where it can be suggested that the support for incremental innovation is likely to be stronger than that of radical innovation due to established socio-technical configurations and economic benefit.

Regional development literature asserts that regional actors may be best placed to create an environment for new technological trajectories. From these perspectives, what impact does the possibility of drawing down economic and clustering benefits have on institutions? Figure 2.4 highlights the complex dynamics that are introduced with the geography of sustainability transitions, and how these perspectives pervade the innovation system. It further highlights the importance of evaluating the role of actors in mobilising change and knowledge sharing.

It can therefore be advanced that this research question explores the overlap of the innovation space of 'insufficient actors for innovation' and the transition space of 'sufficient actors to drive change'. Added to this, the pre-commercialisation nature of the MEI adds a further barrier to negotiate within a pre-commercialisation technology's trajectory between success and failure.

2.7.3 Research question 2 theorising

RQ2: What role do actors and institutions play in embedding technology in places, and what effect do they have on innovation?

Following the initial hypothesis that actors will be the principal regional characteristic influencing sustainability transition, interrogating how actors and institutions embed technology and the impact on innovation is critical. Intermediaries and institutional entrepreneurs are shown to steer behavior through capitalizing on social capital and network relationships. Intermediaries particularly engage with technology actors, where institutional entrepreneurs address insufficient evolution in governance or institutional practice. It can therefore be proposed that there will be evidence of these activities in the case study region due to the likely low number of innovation actors, and transition theorising that those institutions change at a slower pace – potentially problematic where economic benefit is sought from a sustainability transition. In relation to research question one, the hypothesis that there will be fewer actors to enact these changes leads to questions as to whether endogenous change will take place or if it will be driven by exogenous actors. This relates to the postulation that government actors will be motivated to support innovation and transition in a less-developed region.

The next step in the development of the conceptual framework begins to outline the role of intermediaries in connecting different actors to share knowledge, where in the context of a region that is likely to have fewer actors, activities in this arena will need to encourage both innovation and transition. Figure 2.5 postulates how knowledge is likely to flow through the network outlined in Figure 2.4 and how knowledge flow should be facilitated to promote technology development. At the same time, the institutional entrepreneurship literature highlights that actors of a different status can create change, it could therefore be surmised that the distribution and territorial reach of these kinds of actors and actions should also be considered.

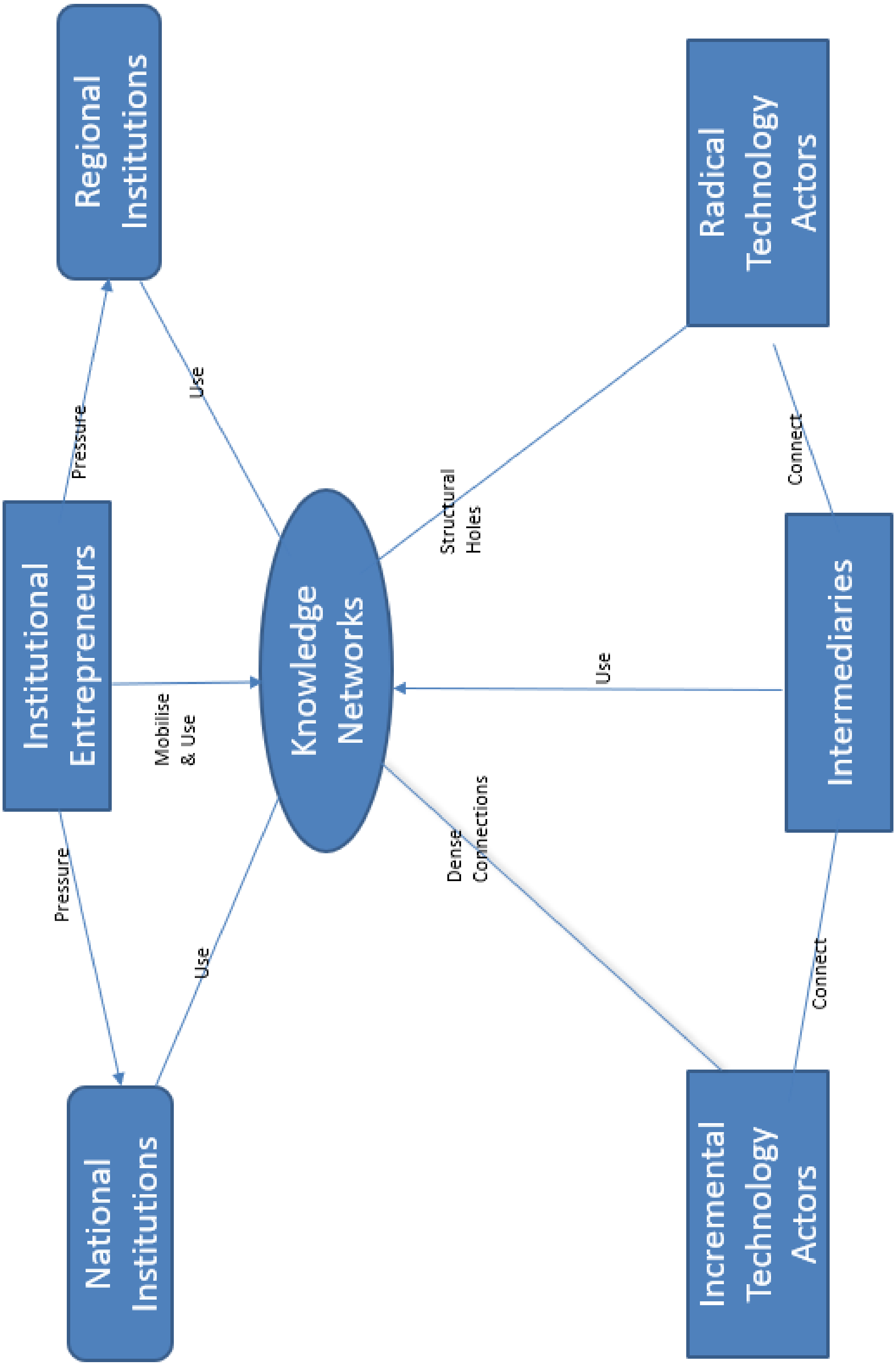


Figure 2.5. Regional knowledge flow for technology development.

Source: Author's own

Figure 2.5 outlines the different implications of knowledge networks. Regional and national institutions use knowledge networks to gain a greater understanding of governance requirements. This diagram reflects the theorising that intermediaries will have connecting relationships with national and regional institutions, as in Figure 2.4, but will not join institutions together in the same way as intermediaries join technology actors. Likewise, it could be advanced that intermediaries will use knowledge networks to gain connections but due to transaction costs will not engage with the networks to the same degree as the institutional entrepreneurs. There remain questions as to whether intermediaries emerge for the new industry, what role they play, and what their limitations may be.

Where institutional voids occur, the possibility that institutional entrepreneurs will mobilise networks to exert pressure on institutions in the absence of sufficient independent resources can be surmised (Fligstein and Mara Drita, 1996; Garud et al., 2002). This suggests the further importance of networks and implies a need to evaluate whether new institutions are emerging in the transition studied and what the implications are of these new activities. In the context of a transition, further research is required on the form and role of institutional entrepreneurs and what activities contribute to success or failure (Hoogstraaten et al., 2020). This includes whether institutional entrepreneurs are a separate entity from the institutions including the innovators (Hoogstraaten et al., 2020), or a set of skills that may be undertaken by a governmental actor.

Technology actors also utilise their knowledge networks to access new information. Drawing on the network literature, denser connections between incremental technology actors may mean less new knowledge flows, signifying a need to seek out new connections. Conversely, it can also be conjectured that radical technology innovators may seek the skills and services of actors that are within the incremental innovation trajectory. Where technology actors do not have access to the information that they need, they are able to engage with intermediaries who utilise their networks to provide the required connection. The role of an intermediary in this instance is to act as a bridging tie (Jakobsen and

Lorentzen, 2015), but may also undertake configuring and brokering to smooth the process of a technology entering a market.

It could be postulated that in the context of a less-developed region, as in the case study, where a lower number of actors is coupled with institutional thinness there may be insufficient capacity to embed a technology in place. This raises questions as to whether activities to pre-domesticate the technology so that it aligns with the existing regime will take place and whether it is possible. Chapter 4 will outline the nature of ME technology and show that wave energy technology could be considered more radical (or niche) than tidal technology. Potentially, there may be a divergence in the activities of actors and institutions to embed these technologies with varied outcomes on the innovation space.

When both stages of the conceptual framework are overlayed to combine relationships and knowledge flows, the complexity of the system becomes particularly apparent. Figure 2.6 suggests that it may be difficult to advance the analysis of a networked approach from a purely qualitative perspective. However, the change mechanisms highlighted in the MLP show that at the core, these relationships contribute to the change mechanisms of market creation and innovation support. With the addition of the region, technology embedding also pervades the theoretical framework and is an important area of analysis within a transition. This leads to the final area of evaluation within this thesis.

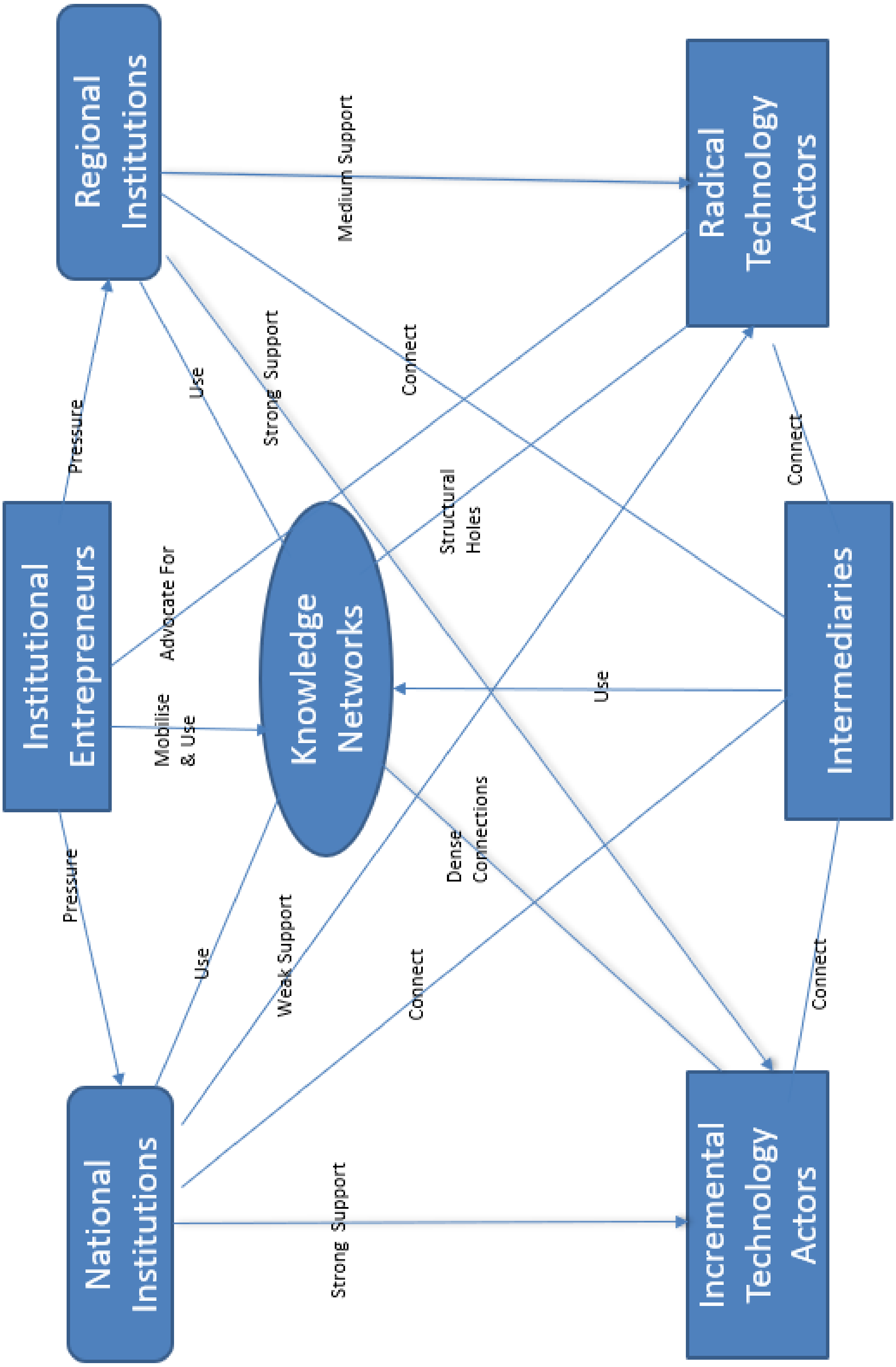


Figure 2.6. Relationships and knowledge networks within transition.

Source: Author's Own.

2.7.4 Research question 3 theorising

> RQ3: How do actors co-ordinate activities to pursue economic development benefits from innovation-driven sustainability transition?

Based on the extant literature, it can be hypothesised that actors are likely to use networks to co-ordinate activities to pursue economic development benefits. Yet co-ordination by networks and economic outcomes are approached in a limited manner in the transition literatures, so it is likely that the evidence will relate more to the literatures on the spaces of innovation rather than transition. However, it is increasingly possible to postulate that innovation and transition spaces need to coalesce for energy transition outcomes (Loorbach et al., 2010). The question that will be explored in the empirical evidence is the extent to which these two aims can be achieved within one region.

In approaching the analysis through an actor's contribution to each system change mechanism, it is possible to better evaluate the collaborative efforts that create change momentum and how these are impacted by regional economic development goals. Moving away from the MLP conceptualisation of actors belonging to levels that instigate change at different rates, it is possible to outline the multiple roles an actor undertakes within an innovation system. It is possible to theorise that the initiatives driven by a regional actor may contribute to incremental innovation in one area or radical innovation in another, and these may sometimes be in tension. Allowing for the consideration of networked activities and joint contributions, market creation, innovation support, and technology embedding mechanisms are useful organising categories to group the activities within a system transition. Through adopting this organisational framework, it is possible to provide a better summation of the empirical evidence as actors can adopt many roles and exert a range of system change pressures. In turn, the activities that pursue economic development will also become more apparent.

Thinking about market creation, innovation support, and technology embedding initiatives highlights how the hypotheses across the three research questions are interlinked, where the outcome and actions in one arena will have a knock-on effect on what can be achieved in others. It can be hypothesised that there will be some features of the region that have a more profound effect than others on the ability to draw down economic development from innovation-driven sustainability transition.

The conceptual framework developed in Diagrams 2.1 – 2.3 do not address transition mechanisms, but conceptualises the likely relationships and knowledge sharing in a region. Through adopting such an approach, the thesis offers insights that are distinct to the government-led documents that are addressed as part of the document analysis. This thesis uniquely investigates regional characteristics as part of the wider mechanisms that contribute to transition, rather than innovation. In the context of a pre-commercialisation niche technology development the thesis also uniquely explores the pathway that is negotiated between success and failure for many niche technologies. The multiple research methods to investigate these mechanisms and their interactions in the context of a region will now be elaborated in the Methodology Chapter.

Chapter 3 Methodology

3.1 Introduction

The first section of this chapter will outline how the transition literatures influence the chosen methodology. Next, the critical realist stance adopted will be evaluated, considering the impact on the gathering and interpretation of data. Section 4 details the methods used and motivations for their use. Finally, the generalisability of the case study and how the data was analysed will be addressed.

3.2 Operationalising the theoretical framework

Chapter 2 advanced a conceptual framework, where the relationships between actors in a region and the flow of knowledge between them were modelled in schematic form. This framework provides a structure for understanding the mechanisms for change that are found within an industry and a region. This is a defining feature of this research as a study of a transition that is taking place.

As highlighted, this presents a methodological challenge in establishing how the actions observed contribute to a change process that does not have an as-yet defined outcome. The MLP, however, is a useful heuristic to capture the wide range of actors and institutions that engage with a system transition.

The conceptual framework does not interrogate the transition mechanisms highlighted in the literature review but seeks to conceptualise the network features that can be found within the region as actors navigate change. In this way it will be more possible to understand how regional actors contribute to transition through their relationships and knowledge sharing. Alongside this framework, the data gathered will be subject to analysis for how actors contribute to the market creation, innovation support, and technology embedding mechanisms. This data will be used to elucidate the theoretical world that has been constructed from a review of existing studies, in line with the ontological stance of the research project.

3.3 Ontology

A researcher's ontology influences how they interpret the world and the "knowledge that can be inferred from it" (Corcho et al., 2003, p.43). The research aim is to explore how regional actors engage with the development of pre-commercialisation technologies, focusing on the challenges faced in a less-developed region.

There is the fundamental assumption of the existence of generative mechanisms that create events (Bhaskar, 1975), making the causal analysis of what links the mechanisms and the events central to critical realism research (Kovacs et al., 2008). This research explores the events within the marine energy industry in Wales (MEIW) that contribute to technology development, the regional embedding of ME technologies, and draw down of economic development benefits within the region.

In this study policy, electricity costs and demand, decarbonisation goals, economic growth, and relationships between actors all influence the socio-technical system. This would suggest compatibility between transition studies and critical realisms' preoccupation with how society is transformed in practice (Bhaskar, 1989).

The goal of critical realism research is not to identify generalisable laws (positivism) or to identify the lived experience or beliefs of social actors (interpretivism), but to develop deeper levels of explanation and understanding (McEvoy and Richards, 2006). If the world is a multi-dimensional open system (McEvoy and Richards, 2006), then employing multiple methods to explore how social structures, mechanisms, and human agency interact is essential. These methods include semi-structured interviews, a policy document analysis, and a Q Methodology.

3.4 Methods

3.4.1 Introduction

Outhwaite (1987) argues that critical realist research entails three steps: the postulation of a possible mechanism, the attempt to collect evidence, and the elimination of possible alternatives. This naturally lends itself to an iterative approach that utilises multiple methods that are outlined in this section. The first step of postulating possible mechanisms is found in the development of the conceptual framework in Chapter 2. The collection of evidence and the elimination of possible alternatives are found in the following chapters, alongside testing of the conceptual framework in Chapter 7. Much like the MLP, critical realism does not favour any one theory or method over another, and is genuinely pluralistic in nature (Ackroyd, 2004; Bhaskar, 1989; Mingers, 2000, 2006).

3.4.2 The case study

Utilising a case study methodology provides a framework for generating data from a variety of sources, gathering a range of perspectives by which to investigate RETs development and the drawing down of regional economic development benefits. This research design is pertinent in studying the case of the ME industry transition in Wales due to the wide range of activities that contribute to socio-technical change. Further, in seeking to understand the spatial implications of transition, many factors influence the system change. A range of methods allows for triangulation and can mitigate against anecdotalism (Silverman, 2010; Yin, 2013). Case studies are typical methods utilised in transition studies, as is the bounding of the study within a nation-state (Raven et al., 2012; Smith et al., 2010). These methods have been adopted as the case study allows for the in-depth exploration of the subject matter at hand, and the nation-state bounding ensures institutional conformity.

Methods that were considered for the case study include innovation biographies - which seek to capture the development paths, knowledge trajectories and stakeholder interactions at an individual technology level (Kleverbeck and Terstriep, 2018). However, the rapid evolution of experiments in the niches meant that even technology developers 'marked for success' were disbanded. This signals how complex the dynamics of pre-commercialisation technologies are. As such innovation biographies as a methodology perhaps align better with MLP approaches to transition analysis, looking back at transitions that have already taken place. This supported the research decision to focus on mechanisms that contribute to transition in the context of a less-developed region, necessitating a consideration of the impact on the generalisability of the study. Table 3.1 summarises the Research Questions and methods that were used.

Research Question	Methodologies Used
How do the characteristics of a less-developed region influence sustainability transition?	Policy document analysis to establish regional scenario; Q method to triangulate actors' perspectives on technology support
What role do actors and institutions play in embedding technology in places, and what effect do they have on innovation?	Semi-structured interviews to understand activities undertaken; Policy analysis evaluating support structure for technology embedding
How do actors co-ordinate activities to pursue economic development benefits from innovation-driven sustainability transition?	Policy analysis to understand support provided; Semi-structured interviews and Q method to understand mechanisms' impact

Table 3.1. Research Question and associated methods.

Source: Author's own.

3.4.3 Potential limits of the research and generalisability

Through research into an industry's evolution, rather than an individual innovation, it is possible to capture a wide range of examples as to how access to innovative capabilities and resources impact transition (Coenen et al., 2012). It is possible to generalise from a single case through an overarching interest in the causal mechanism (Mitchell, 2006), in this case a critical realism stance.

The characteristics that are explored in this study relate to actors within a less-developed region supporting the development of a pre-commercialisation technology. Further, these actors may seek to draw down the economic development benefits of innovation within the region. Whilst pre-commercialisation technology is not often studied, innovation and the securing of benefits for the region could be considered common characteristics within innovation studies. Indeed, this is supported by the swathe of literature previously highlighted, presenting an opportunity for the study of the MEIW to contribute insight to a wider set of phenomena. Furthermore, spatial perspectives such as territory, place, and networks are increasingly explored within transition studies (Gailing et al., 2020), where the in-depth development of a case study allows for the exploration of the different ways in which these manifests.

Furthermore, in undertaking an extended case study of a whole industry, multiple sub-cases arise due to the time period that is evaluated, the number of events consulted, and the multiple technologies that are considered. This allows for intra-case comparative analysis of transition-relevant phenomena. Whilst the wider work is a study of the MEI, there are multiple technologies and experiences within the investigations that provide insight as to whether observations could be considered 'typical'. The next sections detail the methods used to gather this data.

3.4.4 Semi-structured interviews

Semi-structured interviews can be considered the mainstay of qualitative research; providing the opportunity to extensively consider well-defined areas of interest and the potential to discover new information. Critical realist researchers are encouraged to adopt more of such interactive types of interview as to encourage information flow by using social skills (Sayer, 1992). Important to this research, semi-structured interviews include open-ended questions and those that are driven by theory (Galleta, 2013).

A snowballing method was initially used for identifying key participants; this is a useful strategy when networks of individuals are the focus of attention (Coleman, 1958). The initial snowball sampling period generated ten participants, as a result of suggestion-duplication or potential interviewees declining to participant. It was therefore necessary to contact potential interviewees based on participant lists generated by web-based searches and attendance lists for events such as the Marine Energy Pembrokeshire Annual Industry Event. At the conferences scoping interviews were undertaken casually to assess for pertinent organisations. One interviewee from the snowball sample suggested many participants and acted as a gatekeeper to encourage participation in the research.

Through the utilisation of these two selection methods, supported by the gatekeeper, 'saturation' (Glaser and Strauss, 1967) was reached with no new leads suggested and a similarity in the narrative of interviewees. To be eligible for interview, organisations needed to undertake activity in Wales as opposed to expressing interest in Wales through event attendance, this included actors from the wider network that shapes the development of the MEIW. The Crown Estate (CE) was interviewed due to their jurisdiction over the seabed. The Wales-based activity requirement sought to ensure that interviewees had working knowledge of the institutional context. This bounding allowed full exploration of causal mechanisms and included those that did not have 'offices' in Wales, respecting a relational view of space.

The anonymised list of participants and their actor grouping can be found in Appendix A. During the interview period of February 2016 to May 2017, twenty-one interviews were conducted out of a possible twenty-nine relevant organisations that operate within Wales. Of the eight not interviewed, two declined to participate and the rest had only just become involved in activities in Wales as potential developers located in the demonstration zones. Extensive works were required by these organisations before full operation commenced and scoping conversation at conferences clarified that no activities had been undertaken yet. In 2020 these organisations still did not have fully developed operations in Wales, reflecting the slow transition taking place. The interview time frame was longer than designed due initially to the snowballing technique, then followed by the EU Referendum where some participants asked to delay their involvement until they were more confident of any potential changes.

Documentary research into each organisation such as websites, press, and organisational policies helped tailor the interview schedules, with the core questions found in Appendix B. Where an actor was part of the supply chain or a regulatory actor, questions were directly targeted at specific activities undertaken by the organisation. The question schedule guided the conversation and helped validate the interpretation of data that appeared online – did the organisation undertake these activities for the reasons that I, as a researcher, interpreted – or for another reason entirely? Interviews lasted between fifty minutes and two hours. Whilst the interviews were a standalone research tool, they also formed part of the first-tier Q Methodology analysis which will be considered in Section 3.4.6.

The interviews addressed the range of transition mechanisms and included the consultation of regulatory actors who worked alongside or on behalf of the WG. However, following interaction with WG policy makers who declined to participate due to the political uncertainty of the EU referendum, a policy document analysis became a necessary next step in the research. The policy document analysis helps identify the formal rationales for interventions and the specific instruments used to promote technology and regional growth. The next section will detail the method used to evaluate the published energy policies and their impact on the MEIW.

3.4.5 Policy document analysis

The aim of this policy document analysis is to understand the various support measures enacted for ME technology. There are two scales to the document analysis: UK Government policy and that of the WG. In this devolved context, the WG policy can be viewed as a direct action to govern the region and influence the transition. As a result of devolution, however, the WG does not possess all relevant powers for governing the RE sector.

Just over a decade of policy was included from July 2009 until March 2019 and the criteria for selection was that the policies must relate to energy rather than carbon reduction more broadly. It is acknowledged that a wide policy mix is potentially required to foster environmental innovations and address deficiencies in the incumbent system at the same time (Kivimaa and Kern, 2016; Rogge and Johnstone, 2017). However, this strategy was adopted due to the wealth of policies that address carbon reduction, capacity constraints on the part of the researcher, and the need to assess policy intentions within ME. These selection criteria could include economic plans such as job creation or plans for supporting technology innovation.

The policy document analysis navigated the enactment of The Wales Act 2017 on 1st April 2019 with the devolution of consenting powers from 50MW onshore and 1MW offshore to 350MW both onshore and offshore. No primary research was conducted following the enactment of the Wales Act 2017 and - in any case - consenting powers generally attracted very little commentary during interview perhaps due to the pre-commercialisation stage of the technology. The policy document analysis outline was also drafted before April 2019, following the interviews, as part of the Q Methodology process. The policy document analysis was revisited to include 'Prosperity for all: A Low Carbon Wales' (2019), due to its importance to this study as a policy that formed part of the wider RE conversation.

Importantly, the actors involved in driving policy change processes may not be public servants but can include academics and business consultants amongst others (Daniell et al., 2015). The innovation and transition literatures also establish the importance of the contribution of intermediaries and institutional entrepreneurs to system change (Van Lente et al., 2003; Geels and Deuten, 2006; Moss, 2009; Hodson et al., 2013; Kivimaa et al., 2019). This comes as a result of multi-level governance bringing about the evolution in the role and functions of the state, the changing role of cities and regions, and a change in the relationship with non-state actors (Jessop, 1995; MacLeod and Goodwin, 1999; Pierre and

Peters, 2001). This particularly highlights the impact of the regional context and the heterogeneous policy scenarios that interact with technology transition.

It is important to caution that policymaking is an iterative undertaking, and these processes can be shaped by socio-economic conditions, culture, and institutions (Sabatier and Weible, 2014). This document analysis is integral to establishing the system mechanisms, as it encapsulates a wide range of initiatives that may contribute to innovation, market creation, or regional embedding. It is important to remember that to achieve transformative change multiple policy instruments must be implemented over time to address numerous objectives (Loorbach, 2010; Kern and Howlett, 2009).

This policy document analysis provided the spatially specific context of the framework within which the MEIW operates. The policy documents were subjected to a thematic analysis, generating characteristics that impact the development of the MEIW. This analysis coupled with the interviews generated a significant amount of data from which several explanatory narratives for the fate of the MEIW emerged.

3.4.6 Q Methodology

Q Methodology was selected as a method as it seeks to combine qualitative and quantitative research techniques (McKeown & Thomas, 1988; Ellis et al., 2007). Finding patterns in subjective opinions, it is particularly useful in instances where there are seemingly polarised groups, for example the public acceptance of wind farms (Ellis et al., 2007). Q Methodology seeks patterns in what is considered subjective: the experiences of one actor in the MEIW may not mimic another’s, but their world views may converge. To this end, the Q method was a tool to triangulate whether the explanatory narrative established by the researcher through analysis of the interviews and policy documents aligned with the explanatory narrative of industry actors.

There are two distinct stages to the Q Methodology: the Q sorting procedure which is the collection of data using secondary data (such as policy document analysis) and sometimes interviews (Eden et al., 2005), and the Q pattern analysis. The significant question, as with much qualitative research is knowing when the narrative (or concourse as it is termed in Q) is complete; Q, as with other methods adheres to a 'saturation' principle (Glaser and Strauss, 1967). It is essential to remember that "the concourse does not exist 'out there' to be found, but is constructed in the research process" (Eden et al., 2005, p.416). As such, where opinions are expressed by many interview respondents in different ways, these are then more likely to feature within the final statements, but this does not preclude others.

The data gathered in the Q sorting procedure forms the Q concourse, which is then analysed to gather a stock of statements that express topical viewpoints. Statements are then refined to a manageable number where participants are then invited to rank the statements, this ordering is considered to reflect the participant's world view. The ranking of distinct statements makes clear whether opinions of participants converge. It has been said that Q Methodology captures the collective opinion of respondents, "while at the same time identifying subtle differences between some of these voices" (Herrington and Coogan, 2011, p.27).

Literature recommends a Q set anywhere between twenty and eighty statements (Curt, 1994; Stainton Rogers, 1995). Statements must mimic the tone of the concourse - if an opinion is presented in the negative, this must be preserved. Reflecting other practicality issues such as time available to participants, twenty-four Q statements (Appendix C) over the three categories of market creation, innovation support, and technology embedding were issued. Participants were asked to rank statements from one being "Least like how I think" to seven which is "Most like how I think" and asked that they only use the extreme one or seven twice each. In this way they were encouraged to think more deeply about the statements (Webler et al., 2009).

In terms of the number of participants to invite, Q researchers often aim for a ratio of one participant for every three statements. This would mean that the Q Methodology would be complete with eight respondents and nine were achieved. Q statements must represent the “universe of perspectives” (Anderson et al., 1997, p.338), so too must participants be representative of the stakeholder groups and have well-formed opinions. Participants should also be chosen for comprehensiveness and diversity, rather than representativeness. These requirements typically mean that respondents will be better able to engage with the process and produce a more robust sort. The sample in this Q sort were a subset of the interview respondents, selected initially due to their experience and representativeness of the range of actors engaged with the MEIW.

At the time of conducting the Q Methodology in 2019, participants were refreshed on the nature of the research and informed consent was once again secured. The Q Method was conducted online utilising ‘Google Docs’ linked to a password protected account constructed for the sole purpose of the research. Participants were anonymous but were able to leave their email address should they wish. This is not the typical Q Method adopted, where secondary data is typically used and face-to-face interaction with participants comes after the generation of statements.

In this instance, the Q Method was conducted in this way due to the limited secondary data that is available on the MEIW and the time constraints of the participants. Having previously spent multiple hours conversing with the researcher, it was judged as more likely to encourage engagement were the task kept timely. Overall, engagement was excellent - most likely due to the sustained interactions between the participant and researcher over the course of the investigation and the social capital that had been developed. All participants took the time to explain each decision which emulates the approach of in-person Q Methodology research.

3.5 Analysis of interview and documentary data

This research aims to evaluate how regional characteristics influence sustainability transition that is led by technology innovation, and how economic development benefits might be secured. Concurrently, consideration is given to outcomes and events that also failed to materialise. Through understanding the mechanisms that contribute or detract from technology development it will be possible to establish factors that contribute to system transition. In the context of a less-developed region it will be possible to evaluate how this precondition impacts system change.

Interviews were recorded where participant consent was obtained and transcribed allowing for a fuller qualitative analysis of the information that was shared. Where recording was not permitted field-notes were taken during interview, and a fuller conversation script drafted immediately following the interview. An anonymised coding system (Appendix A) was used to store the data and to reference within the research. NVIVO was utilised for analysis in order to draw out key themes.

Interview material was double coded, once for general themes, then along a structured system for evidence pertaining to the research questions (Appendix D). The policy document analysis adopted a similar method to the interview material, with coding for general themes and along a structured system (Appendix E). The list of the twenty-one policy documents analysed are found in Appendix F.

This analysis activity created the structure and general themes from which the Q statements were generated. The Q statements were analysed utilising an online package 'Ken-Q Analysis Desktop Edition' due to its accessibility and ease of use for those that are non-expert with statistical packages such as R. A combination of Principal Component and Varimax Rotation were used for a consistent approach to analysis. Factors in the case of Q Methodology are a group of individuals with similar opinions, those with an Eigenvalue over 1 were selected for analysis. An Eigenvalue over 1 signifies that the Factor explains the opinion of more than one member of the group.

The results of this analysis are presented in chapters 4 through 7, where the interviews and policy analysis inform the study of transition and the Q Method provides triangulation of the themes that emerged from the first stage of analysis. These measures go some way to ensuring the reliability of the data, where other factors are considered in the next section.

3.6 Ethics, ensuring reliability, and validity

Ethics approval was sought from the departmental committee before any research was conducted. All participants were adult professionals who represented their organisation, allowing informed consent and no contact with vulnerable individuals. Participants had the nature and process of research explained to them through an initial email, with consent confirmed at this point and a meeting date arranged. At the time of the meeting, the details of the research were once again discussed, and consent noted. It was made clear that no commercially confidential information was required, but participants were able to speak freely due to the anonymisation process.

Due to the limited number of actors that are part of the MEIW, it became apparent that it may be possible to ascertain who expressed the opinion should direct quotes be utilised in the analysis chapters. Participants were assured that an anonymised coding system would be used, and consent would be sought were they to be directly quoted. Most thought that due to the very open dialogue within the industry in Wales that they would have voiced these opinions at some point in a public audience.

A potential problem with validity is the vote to leave the EU. The empirical evidence highlights the substantial role played by the EU and conclusions drawn may become invalidated following the UK's exit from the EU. However, the role that is played by the EU is that of a government and therefore the observed activities could be quite simply replicated by another authority. This will be elaborated further in the conclusion.

The study of transition 'in action' by its nature addresses a rapidly changing industry, and key to the continuation of this type of research is the ability to generate similar outcomes if the study was repeated. The methods utilised are replicable, and the range aimed to limit some of the subjectivity of the researcher's interpretation (Babbie, 2010). The Q method in particular addresses both the researcher and respondent's subjectivity as the generation of fixed stimuli with a numerical response limits the number of interpretations possible.

As highlighted, a range of methodologies were considered with the aim of fully encapsulating the evolution of MEIW, with the most appropriate being selected within this dynamic field of study. An initial snowball sampling method to trace the networks of associations within the industry was insufficient, and so the approach was extended to embrace web-based searches and attendance lists for industry events. This could be considered to say something about the nature of the network of a pre-commercialisation industry, where it is likely that there will be structural holes. Were this method to be used again when the technology has developed more in Wales it may generate a different result and a greater number of respondents. In all, the multiple research methods considered, used, or discarded seek to improve the reliability and validity of this research.

As outlined in Section 4, this thesis has many stages of analysis, and as such will be organised into three analysis chapters that are structured around the groups of change mechanisms identified in Chapter 2 of market creation, innovation support, and technology embedding. The next chapter will set the case study context, to understand the framework within which these activities take place. Following this, Chapter 5 examines policy and institutions in Wales and efforts towards market creation. Institutional deficiencies will be highlighted and consideration given to whether institutional entrepreneurs are emerging to address institutional voids. Innovation support (Chapter 6) will consider innovation efforts and whether knowledge networks are forming and how knowledge is shared among actors. Finally, technology embedding (Chapter 7) will focus on evaluating efforts to encourage technology development and economic development benefit embedding within a region. These categorisations will be used to reference the sum of activities within each mechanism.

Chapter 4 Case study context

4.1 Introduction

The purpose of this chapter is to set the wider background of the region under study, in order to support this investigation of the framing of place as a context for transition (Binz et al, 2020; Jensen et al., 2016; Murphy, 2015; Truffer et al., 2015). Wales has a complex industrial and economic development history; through a better understanding of the economic and governance context, it is possible to understand the causal mechanisms that drive regional activity and the capacity of actors to engage with the MEI transition (O'Sullivan et al., 2020).

Wales is an interesting case as it has capacity for self-determination as a result of devolution yet is not self-reliant in economic terms. Alongside the regional context, global patterns of activity in the ME also influence development in Wales; global patterns will be considered before summarising the key developments in the marine energy industry in Wales (MEIW).

4.2 Wales, devolution, and the economy.

4.2.1 Devolution

The institutional context of Wales is shaped by devolution. Democratic devolution commenced in the UK in 1997 and created governmental subregions with differentiated legislative powers. The process of devolution transferred existing decentralised powers to new political bodies, creating governmental subregions with different legislative powers. Some powers were retained by the UK Government, and the WG has twenty areas of power which include economic development, the environment, planning (except major energy infrastructure) and local government (UK Government, 2018).

The Welsh economy is significantly influenced by the UK national economy due to the devolution arrangement and trade relationships with England. There is, however, a distinct set of regional characteristics and challenges in Wales; this shared government, culture, and heritage (Lundvall, 1988; Markard and Truffer, 2008) make it suitable for research exploring how spatial aspects influence transition.

Established in 1998, the Welsh Assembly was initially given limited jurisdiction with secondary (not primary) legislative powers, no power over taxation, macroeconomic policy or the ability to pass primary legislation. The paradox of Welsh devolution was that more was expected of the country in terms of economic development, yet it was given less constitutional power than Scotland with which to make the change (Morgan, 2007). A clause was added to the Government of Wales Act requiring the WG to “make a scheme setting out how it proposed, in the exercise of its functions, to promote sustainable development” (Government of Wales Act, 1998, sect.121). This clause is a defining statutory obligation which cannot be delegated and therefore represents a highly unusual constitutional obligation that makes Wales one of the few governments in the world with sustainability at its core. Arising from this, the WG has created an array of environment-focused interventions that includes: One Wales; One Planet (2009); Capturing the Potential, A Green Jobs Strategy for Wales (2009); and the Well-being of Future Generations Act (2015). In 2006, devolution was further formalised with the Government of Wales Act (2006) which created the executive institution known as the Welsh Government (WG) which is referred to throughout the thesis.

The devolution of power in the UK energy sector highlights that “the pursuit of functionally preferable scalar arrangements for addressing environmental problems unfolds alongside constant spatial churning in governance arrangements” (Cowell et al., 2017b, p.481). The devolution exercise was not an attempt to achieve better institutional ‘fit’ (Moss and Newig, 2010) and devolved powers vary across relevant sectors. Within the energy sector, following enactment of The Wales Act 2017, further powers over consenting were devolved to the WG (Figure 4.1).

	Onshore	Offshore
Pre 1st April 2019	<50MW	<1MW
Post 1st April 2019	<350MW	<350MW

Figure 4.1. Devolution of renewable energy consenting powers to the governmental bodies in Wales.

Source: Author's own.

In the period before 1st April 2019 the UK Marine Management Organisation, a Defra sponsored public body, had consenting power from 1 to 100MW of offshore energy generation. All projects also required a marine license under Section 65 of the Marine and Coastal Access Act (2009) alongside the main consent (Orford and Henderson, 2018) which was issued by Natural Resources Wales (NRW). For projects over 100MW, such as tidal lagoons with the Swansea Bay Tidal Lagoon at an output of circa 320MW (Tidal Lagoon Power, 2020) and North Wales Tidal Energy circa 250MW (North Wales Tidal Energy, 2020), a marine license was required, and the project must be granted a Development Consent Order by the UK Secretary of State. The WG remains with limited powers with respect to market support mechanisms, grid regulations, and consent of the use of the seabed, which is integral to marine energy. This will be elaborated further in Chapter 5 when considering market creation activities.

4.2.2 The Welsh economy

Chapter 1 highlights Wales' long industrial history of energy, where coal has been a prominent source of economic wealth and employment. Welsh income per head in 1891 was estimated at 96.2% of the UK average (Crafts, 2005), as of 2019 this was around 90% (Statistics for Wales, 2019). This hints at the considerable structural change that has taken place over a century; major contributing factors are the loss of traditional heavy industry jobs from the mid-1970s (Beatty and Fothergill, 2011, 2016) and the virtual cessation of coal-mining activity in the 1980s. Arguably the decline in these industries had a greater impact on the Welsh economy than the 2008 recession (Bristow, 2018). This major source of regional wealth was not replaced with a "new economic vocation" (Morgan, 2017, p.575).

In terms of its innovation potential, the EU's regional innovation scoreboard ranks Wales as one of the weaker performing regions in the UK despite significant improvements in potential in recent years (European Commission, 2019). These factors contribute to Wales having the lowest GVA per head at the NUTS1 level in 2017 (Office for National Statistics, 2018). NUTS refer to the 'Nomenclature of territorial units for statistics' and the different levels refer to different size territorial units, with NUTS1 being the largest. Within this investigation of regional characteristics, and due to the complexity introduced by devolution with Wales as a region of the UK, the different scale NUTS will be referenced. The Wales territorial unit is a NUTS1 level, and Pembrokeshire and Anglesey Island are NUTS3 regions (where the marine resources are found).

These economic development figures hide the significant geographical variation in Wales, with the West Wales and Valleys NUTS 2 region qualifying for EU Objective one status in 1999 with a GVA per head of 64.5% of the UK average (StatsWales, 2021). Conversely, East Wales had a GVA per head that was 90% of the UK average. In 2018, GVA per head in West Wales and the Valleys was at 63.5% of the UK average and East Wales at 88.5% - hinting at the ongoing regional development issues.

In West Wales and the Valleys, some convergence funding has been allocated by the WG to the MEI to support innovation. The European Regional Development Fund (ERDF) and the European Social Fund (ESF) are managed by the Welsh European Funding Office (WEFO). The funds support work and training, research and innovation, renewable energy and energy efficiency amongst other areas. The two main regions of marine energy resources in Wales, located near to Anglesey Island and the coast of Pembrokeshire are within the eligible areas (Figure 4.2). Some £2 billion in ESF were programmed for Wales during the period 2014-2020 with over £100 million prioritised for marine energy.

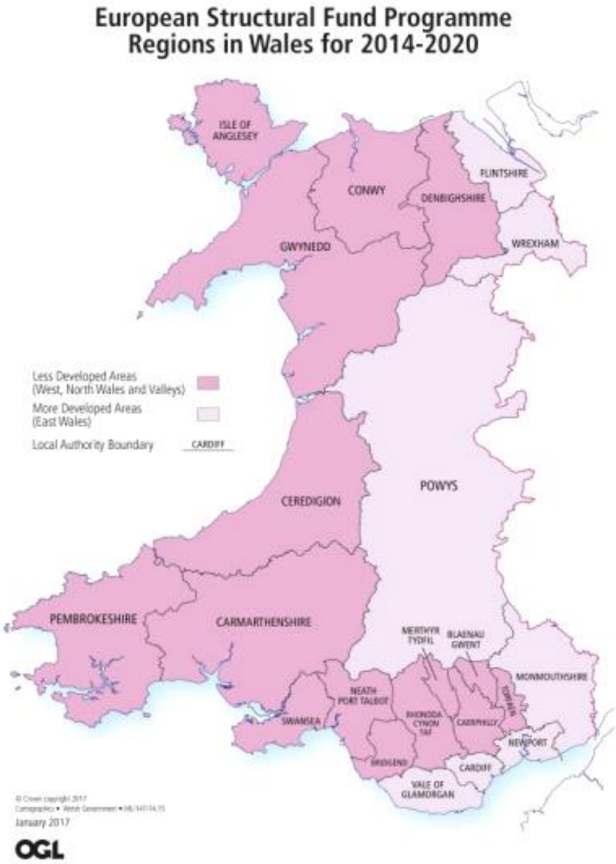


Figure 4.2. European Structural Fund Programme Regions for Wales 2014- 2020.

Source: Welsh Government, 2017

Since the 1990s, EU regional policy has sought to enable regions to become actors in the policy-making process by giving lagging regions the resources to catch up (Bailey and De Propris, 2019). Since this juncture, key strategies have further consolidated the link between innovation and regional growth, such as the Lisbon Strategy in 2000, and the 2010 'Europe 2020 Strategy' - linking sustainable and green growth. These provide the foundations on which the WG has developed policy initiatives that link RETs and economic growth, so that businesses can "be equipped to face the future with confidence, by seizing opportunities for growth and increasing their competitiveness" (Welsh Assembly Government, 2009, p.2). This has subsequently contributed to the utilisation of EU funds within the MEIW.

4.3 Marine energy technology and its progress in Wales

4.3.1 Marine energy technology innovation challenges

The introduction outlined the wide range of social and technical challenges for ME technology development. There is an estimated 10-year lag for wave energy development behind that of tidal energy (ORE Catapult, 2018) and the technical challenges for the technology types are different. The social challenges for both technology types include the complexity of establishing the environmental effects of the technology; wave and tidal devices produce different impacts on the environment and as a result there is limited universal data (Copping et al., 2014).

The location of the wave resource is important as devices typically operate in a deep-water environment; but cabling is expensive, meaning that suitable deep water needs to be close to land (Mossy Earth, 2020). This means that potentially exploitable resources are localised (Figure 4.3), and Wales has been identified as having potential for both wave and tidal. Fossil fuel dependent energy is configured to “large, geographically remote and constantly running plants” (Johnstone et al., 2020, p.3) and the existing electricity grid structure is therefore configured to large scale generation. ME technologies align with a decentralised energy system, which is responsive to the local patterns of supply and demand. In order to integrate RETs into the grid infrastructure there is a need to reconfigure the existing system and ME technology requires grid that extends to the foreshore and beyond.

Figure 4.3. Global marine energy resources.

Source: Wave Hub, 2012.

The key innovations in tidal energy utilise learning from other sectors such as oil, gas, and wind. There are four principal areas of innovation focus: reliability, structures and moorings, offshore operational costs, and electrical connectors. At the same time, whilst reducing costs in the innovation stage is necessary, the maturing of the industry will also reduce the cost of capital once the technology is assessed to be less risky. However, wave technology is a more complex process as it does not utilise learning from other sectors. As such the ORE catapult report referenced here was unable to analyse the potential areas and scope of cost reduction due to the “high uncertainty in design and yield potential” (ORE Catapult, 2018, p.19).

This uncertainty of cost is reflected throughout UK and Welsh policy, where there is recognition of the role to be played by the respective governments. Within this policy context, nuclear is positioned as ‘low carbon’. UK policy has operated with a dual focus on creating a:

“supportive climate for the substantial new investment needed to bring forward low carbon infrastructure and maximise the economic production of oil and gas from the North Sea to help secure the continued fossil fuel supplies needed during the transition” (UK Government, 2009a, p.7).

4.3.2 Marine energy progress in Wales

Wales has excellent natural resource availability for both wave (Figure 4.4) and tidal (Figure 4.5) energy, with increasing interest on the part of technology developers. The resources are in regions that are remote but due to existing hydrocarbon capabilities have appropriate electricity network infrastructure (pink line on both Figure 4.3 and 4.4). Further, Wales' marine heritage with ports and supply-chain infrastructure provide opportunities not only "to reduce carbon emissions and promote sustainable energy, but also include the potential for industrial and economic regeneration" (Welsh Government, 2012a, p.1). At the same time, there is a need "for a major effort to market the potential of Wales as a place for renewable energy developments" (Welsh Government, 2012b, p.18). The particular opportunity for the industry in Wales is to expand on the existing hydrocarbon capabilities and to utilise natural assets such as deep-water ports.

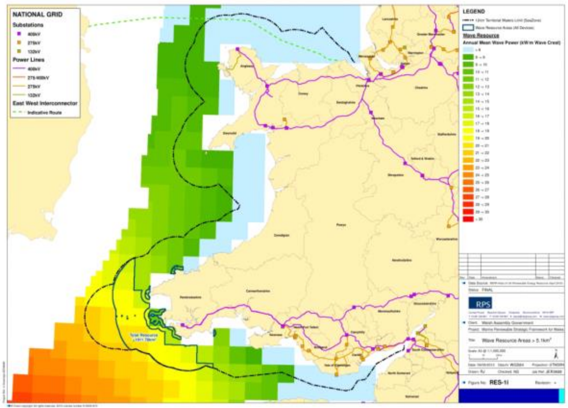


Figure 4.4. Wave energy resources Wales.

Source: RPS for MRESF study.

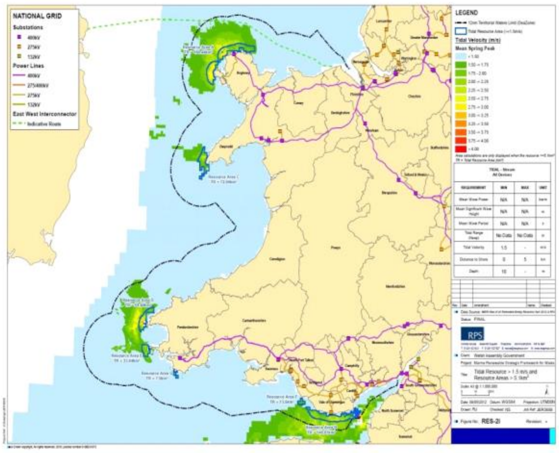


Figure 4.5. Tidal Energy resources Wales.

Source: RPS for MRESF study

In 2018 there were twenty-two tidal device developers and twenty-three wave device developers active in the UK, “despite a number of high-profile failures” (ORE Catapult, 2018, p.3). Two of these high-profile ‘failures’ or disbanded technology developers were in Wales, where two tidal stream, one tidal lagoon, and four wave developers remain active in 2020.

Activities in the marine energy sector began in Wales in the mid-2000s, with TD6 engaged with Anglesey whilst based in Bristol and TD4 engaged with Pembrokeshire whilst based in Cardiff. Greater focus came to the sector when Pembrokeshire Coastal Forum initiated Marine Energy Pembrokeshire (MEP) to explore the opportunities presented by the marine energy sector. MEP was formed in 2010 and Welsh policy attention to marine energy commenced in 2011. The developers in Wales are summarised in Table 4.1, some will have indirectly received EU funding through collaboration with Welsh Universities.

Developer Name	Technology Type	Type of innovator	Stage of development by 2020	Region	Direct ERDF amount
TD1	Wave energy	Innovation start-up	Demonstration	Pembrokeshire	£3 million
TD2	Tidal Lagoon	Innovation and investment management	Seeking investment	Anglesey	0
TD3	Tidal stream	Multi-national innovation	Demonstration	Anglesey	Euro 40 million
TD4 (disbanded)	Tidal stream	Innovation start-up	Device in water but disbanded	Pembrokeshire	£8 million
TD5	Wave energy	Innovation start-up	Testing	Pembrokeshire	£4 million
TD6 (disbanded)	Tidal stream	Innovation start-up	Testing but disbanded	Anglesey	(£10m UK funding)
Swansea Bay Tidal Lagoon	Tidal Lagoon	Innovation and investment management	Seeking investment and Govt. consent	(Pembrokeshire)	0
Bombora	Wave energy	Innovation start-up	Demonstration	Pembrokeshire	£10.3million
Repetitive energy company	Tidal stream	Innovation start-up	Technology development	Pembrokeshire	0
NOVA Innovation	Tidal stream	Multi-national innovation	Demonstration array	Anglesey	0

Table 4.1. Developer, location and EU investment in Wales as of 2020.

Source: Author's own.

It can be seen from Table 4.1 that there are a range of developer types in Wales, but the majority are innovation start-ups with engineers, many of whom met in university, working on a technology that they have invented. This means that many of the individuals behind these technologies are technology-focused, seeking to invent a radical new-to-market technology. As will become apparent throughout the empirical evidence, these engineers are then required to undertake subsidiary activities to progress the technology more widely. As the company grows, many take on additional staff to address the range of functions fulfilled in creating and marketing a successful innovation. TD2 and the Swansea Bay Tidal Lagoon are marked as 'innovation and investment management' as the technology utilises many accepted energy generating principles (traditionally used in hydro-electric dams), but the challenge faced by these organisations relates to the vast sums of money required to install the technology. As such, it can be concluded that innovation and transition activities are being undertaken by these developers, all with the aim of promoting different aspects of the innovation spectrum.

In order to provide some context to the development of the marine energy sector in Wales (MEIW), Table 4.2 outlines some key developments. These can be considered the outcomes of efforts towards technology transition, and the events will be explored in more detail in subsequent analysis chapters. The period covered commences in 2013 coinciding with detailed research; due to Wales somewhat limited policy attention commencing in 2011, this period covers much of the transition time period. However, the data is most reliable from 2015 when MEP began systematically to share the news of the MEIW on its website and through its newsletters. This is one of many examples of MEP's efforts to systematically disseminate information on the MEIW. Where it may be possible to easily connect the name with the anonymised data, the anonymised coding is utilised.

Year	Month	Outcome
2013	Feb	TD6 consented
	Feb	TD6 receives funding from UK Government
	June	House of Common’ Energy and Climate Change Committee say Severn Barrage proposal unproven following Severn Tidal Power Feasibility Study 2008 – 2010
2014	Aug	TD4 device officially unveiled
	Oct	Directional Waverider buoy launched in Pembrokeshire
2015	Nov	Offshore Renewables Joint Industry Programme website goes lives
	Dec	TD4 installs off Pembrokeshire Coast
2016	N/A	Task and Finish Group Report
	July	Opening of Marine Centre Wales, Bangor
	Aug	Pembrokeshire’s new marine hub opens
	Oct	8 berths signed up at Anglesey Demonstration Zone
	Oct	TD4 in administration
	Nov	Marine Energy Wales launched
	Dec	TD1 constructing WaveSub
2017	Jan	Royal Assent ‘The Wales Act 2017’
	Mar	Swansea Bay City deal signed by Prime Minister Theresa May
	Mar	TD5 begins sea trials for Wave Rower
	July	Pembrokeshire Coastal Forum secures funding for supply chain project
	Aug	Coastal communities funding for: Mainstay Hoist, NOVA expansion in Wales, and Marine Energy Testing Area
	Sept	Money to further Morlais activities from EU and WG
	Oct	TD1 unveils quarter-scale WaveSub for sea testing

Year	Month	Outcome
	Nov	MEW wins award for 'Outstanding Advocate' at Green Energy Awards
2018	Jan	TD1 WaveSub at sea for initial stage of testing
	Jan	WG announce their support for the Swansea Bay Tidal Lagoon awaiting UK Government response
	April	Marine Hub and MEW collaborate, funded by the WG
	May	BEIS inquiry into the UK Government's activities around Swansea Bay Tidal Lagoon
	June	UK Government withdraws support for Swansea Bay Tidal Lagoon
	July	TD5 installs at Fabtest, Cornwall
	July	Scotland and Cornwall to support development of Marine Energy Test Area
	Sept	TD3 deploy utility-scale device Anglesey
	Oct	TD3 generates electricity
2019	Feb	TD3 explored options in the Caribbean
	April	Bombora is selected by Enzen for Lanzarote Energy consenting powers further devolved to WG
	May	All party Letter of 91 MPs demanding support for UK ME development
	July	Wales-Ireland cooperation formalised
	Oct	First Wave licence in Wales granted to Bombora
	Dec	Grant funding for floating wind technology development

Table 4.2. Key Outcomes in Marine energy sector in Wales 2013 – 2019.

Source: Author's Own,

It should be noted that the time frame over which these events develop is substantial, outside the time frame of the scope of this research the Severn Barrage is a technology that has received attention in Wales since the mid-1980s. This technology has been widely opposed in Wales and Southwest England spheres due to the scale and forecasted impact of this technology, this includes the habitats of protected species, impeding the navigation of large ships into ports, and infrastructural issues on how the electricity generated would be integrated in the grid (Friends of the Earth Cymru, 2007). It is possible that this narrative around the barrage has influenced the trajectory of the MEIW, however, participants did not refer to the barrage and there is limited reference in contemporary policy.

A more recent example of the protracted timeframe within which these events develop is that TD4 published a scoping report on the Pembrokeshire region in 2008, installing a demonstration device off the coast of Pembrokeshire in 2015 and due to device failures and financial issues, the developer went into administration in 2016. The development of a new industry is typically slow, with transition taking many decades (Kanger and Schot, 2016); this is particularly the case with ME due to the challenges of establishing environmental interaction, the required durability of device design, and the challenge of different marine environments. These aspects will be explored in more detail through this research. The following analysis chapters will disaggregate these events by taking sets of transition mechanism in turn, highlighting 'failures' and discussing the likely inhibitors and promoters of the activities.

4.4 How representative is marine energy of sustainability transition?

ME is a pre-commercialisation technology, and with reference to the MLP could be considered to be at the earlier stages of the niche where multiple experiments are taking place that sometimes lead to failure. This raises some questions about how representative ME can be of a transition. As highlighted in the methodology, much of transition study elaborates on changes that have already taken place with technologies that are deemed to be successful.

The decision to study a pre-commercialisation technology as part of a transition in action had several motivations, uniquely seeking to explore the trajectory of a technology that is somewhere between success and failure. There are a wide range of insights that can be gained, even if ME does not reach an end point that could be considered 'success'. In the context of ME, success could be defined as integration into the grid in the UK or becoming a technology that is utilised in island nations as modular technology to power smaller communities. Indeed, this technology could also be used in hard-to-reach coastal places also.

The benefit to studying a transition as it unfolds, from the perspective of the niche is that many of the nuances and agentic motivations can be captured at the time that they take place. In the more 'traditional' transition studies, it is possible that aspects might be missed the further the distance from the event and innovation process. To capture the key actions and actors that influenced the technology trajectory will give a deeper understanding to the transition process. Understanding the agency of actors as they seek to innovate and promote a pre-commercialisation technology such as ME extends transition literatures and addresses a gap in knowledge. In many instances, the technologies that drive sustainability transition were part of niche dynamics. In this way, studying ME as a pre-commercialisation technology can be considered representative of all transition stories as it is able to capture the steps along the journey to success or failure. This makes this study unique as it has a special interest in actors and their agentic undertakings. It will be possible to better understand the types of relationships that may exist between technology and government actors and the beliefs of what needs to take place in order for change to happen.

As such, this raises issues around innovation and transition spaces, it can be argued that in order for transition to take place, the innovation process must be successful in generating a technology that can produce electricity at a competitive price. However, as research has shown, the occurrence of purely 'break through' technologies that do not respond in any way to market conditions are rare. Therefore, it is necessary to identify and drive towards a space in the marketplace which is simultaneously created utilising 'pull' principles whilst innovators work on the ‘push’ element of a creating an appropriate technology. This research seeks to address both innovation and transition literatures in order to best understand and conceptualise how these spaces intercept and interact. This is an opportunity provided by the study of a pre-commercialisation technology such as ME, where processes of experimentation are taking place in parallel with transition functions, meaning that the research seeks to capture these developments simultaneously.

It can therefore be concluded that the generalisability of this study is broad and addresses a particular phase of niche development with a high level of detail, detail that may be overlooked or lacking in sufficient contemporaneousness in transition studies that are undertaken once an end state is reached.

Chapter 5 Market creation

5.1 Introduction

As highlighted in Chapter 3, the analysis chapters will consider the causal mechanisms within sustainable transition. This chapter will address market creation activities such as energy pricing, policy, and the actions of key government actors. The multiple actors that contribute to market creation highlighted in Chapter 2 are increased by devolution, with the main policy actors the United Kingdom Government (UK Government) and Welsh Government (WG). These actors are theorised to have a vested interest in enabling innovation and sustainability transition, with the principal area uniquely within their control being that of market creation.

Aside from the UK Government and WG that issue and enact policy, the most significant institutions that interact with the marine energy industry in Wales (MEIW) are the Crown Estate (CE), Natural Resources Wales (NRW), and Wales European Funding Office (WEFO). Engaged with the consenting and licencing process, the CE operates at a UK-level and NRW has authority within Wales only, again demonstrating the different levels of governance that the MEIW must negotiate. As outlined in Chapter 4, WEFO administer European Union (EU) funding that is utilised by technology developers and will be considered fully in the innovation support chapter (Chapter 6).

The aspects that are considered within this chapter contribute to market creation through enabling the integration of the new technology in the socio-technical regime for energy (Freeman and Perez, 1988) and by stimulating demand for the method of energy production. UK Government policy including the market mechanism of electricity price will initially be addressed. Next, how the WG engages with the industry as a lower tier government actor in a less-developed region will be considered. The transition mechanisms introduced through multi-level governance considered essential for environmental governance (Bulkeley et al., 2003) will be highlighted and includes evaluation of the WG-sponsored agency NRW. WG's expression of agency will then be explored through policy documents and industry groups, where the dominant focus is growth. Finally, the main market creation events of the last 5 years will be evaluated, and conclusions drawn.

5.2 UK Government electricity price mechanisms

5.2.1 Overview

The desire to rapidly encourage technological change to low carbon power generation has created a need for targeted market support (Bunn and Yusupov, 2015). The creation of appropriate conditions and increasing market certainty are used as a signal to technology developers. Through reducing risk for energy generators, a wider range of projects become attractive as lowered risk also reduces capital costs (Mitchell et al., 2006).

There are multiple ways in which the UK Government can influence energy market transition; both through discouraging incumbent technologies or supporting new 'low carbon' or renewable energy technologies (RETs). Policies related to the pricing of electricity can signal market intentions and - depending on their design - introduce risk or certainty for developers. Electricity pricing policies are not devolved in Wales, meaning that the WG have no control over these market mechanisms.

With the institutionalisation of more stringent carbon reduction targets, questions were raised whether the liberalised energy market was fit for purpose (Ofgem, 2009; DECC, 2010). In response to this, financial support mechanisms were devised by the UK Government, and two in particular shape the ME market - Renewable Obligations (RO) and Contracts for Difference (CfD). It could be said that despite the significant focus on technological design in the study of RET innovation, it is the electricity produced that is the principal 'product'. Therefore, it is possible to suggest that the control of the value of this electricity has the greatest ramifications for technology development with respect to market creation mechanisms – as indeed has been the case in the early phases of wind and solar photovoltaic technologies. These mechanisms have been used by the UK Government with a wide range of approaches, both on the type of technology favoured such as wind or nuclear, and the intricacies of device design. The pre-commercialisation status of ME is notable and whilst developers are not yet connected to the grid, the electricity funding framework influences the risk of investment.

5.2.2 Renewable Obligation Certificates

Renewable Obligation Certificates (ROCs) were introduced in 2002 to provide incentives for large-scale renewable electricity in the UK, requiring licensed UK electricity suppliers to source some RE as part of the supply to customers. The system allocates ROCs to accredited RE generation stations, suppliers then use the certificates to demonstrate obligations have been met. Crucially, as suppliers can source RE from any generator, "generators were competing to sell their output to suppliers at the most attractive price" (Woodman and Mitchell, 2011, p.3915).

Where a supplier did not meet the required level of certification, an equivalent amount was paid into a buy-out fund. This represents a financial penalty for failing to utilise enough RE (Ofgem, 2020). Effectively, an upper limit was put on the energy price as suppliers could simply elect to pay the 'buyout price' per megawatt-hour (Woodman and Mitchell, 2011). As a result of devolution with its limited tailoring to the nation state system, there are three ROCs systems in place in the UK: England & Wales, Scotland, and Northern Ireland. ROCs can be transferred between the different nations, thus creating a single UK market (Cowell et al., 2017a).

Initially, and until 2009, 'green energy' was allocated 1 ROC per megawatt hour with the aim of being technology neutral (Woodman and Mitchell, 2011); but from 2009 a banding system was introduced, as highlighted in Table 5.1. This banding system aimed to reflect the different levels of technological readiness.

However, 2009 – 2013 witnessed a spatial divergence in the three systems within the UK, with wave and tidal power projects disadvantaged in England & Wales when compared to Scotland. Higher ROCs per megawatt hour could be argued to encourage developers to locate in Scotland. This exhibits clear pro-active governance on the part of the Scottish Government in bolstering regional market creation and technology embedding. Whilst the ROCs returned to cross-national consistency in 2013, the four-year Scottish lead is not insignificant as “this ‘first mover’ action contributed to the greater growth of commercialisation and testing facilities” (Cowell et al., 2017a, p.174). Scotland as a region was able to capture many developers and strongly signal support for the industry. This is a reputation that remains prevalent a decade later with the development of the world’s most powerful floating tidal turbine amongst other technologies (BBC, 2019).

Technology	2009 - 2013	2013/ 2014	2014/ 2015	2015/ 2016	2016/ 2017
Enhanced tidal stream (Scotland only)	3				
Tidal barrage <1GW	2	2	2	1.9	1.8
Tidal lagoon <1gw	2	2	2	1.9	1.8
Tidal Stream <30MW	2	5	5	5	5
Enhanced wave (Scotland only)	5	5	5	5	5
Wave	2	2	2	2	2
Solar photovoltaic	2				
Solar photovoltaic - building mounted	New	1.7	1.6	1.5	1.4
Solar photovoltaic - ground mounted	New	1.6	1.4	1.3	1.2
Offshore wind	2	2	2	1.9	1.8
Onshore wind	1	0.9	0.9	0.9	0.9

Table 5.1. Renewable Technologies and Renewable Obligation Certificates per MWh. Source: DECC, 2010.

It could be argued that whilst there was this initial disparity between the Scotland and England & Wales systems, from 2013 onwards alterations were made to boost the market for tidal stream across the board. A higher ROC level was allocated to tidal stream in England & Wales than other ME technology types and could be considered a clear indicator of technology preferences on the part of the UK Government. In the context of Wales, barrage and lagoon technology are thought by many to be favoured over other ME technology types (TD1, TD5), highlighting a disconnect between English and Welsh transition goals. These variations counter much of the transition literature that emphasises a need for shared goals.

Within UK policy, signals of the change of outlook appeared in the 2010 'Marine energy action plan' which considered that ROC levels were too low to support development. At the same time however, the policy signalled that the "support levels also need to take into account the impact on energy consumers" (UK Government, 2010a, p.10), signalling the recurring theme of cost-to-the-customer that is prevalent in RE policy, especially since 2010.

'The Energy Policy and Planning in Wales' and 'Energy Wales: A Low Carbon Transition' policies both published in 2012 asserted that the WG would engage with the UK Government around the market mechanisms of the Electricity Market Reform. The WG promised to ensure fast notification and implementation of changes related to the ROC in order to create stability and provide "a more equitable and stronger support mechanism for marine energy in Wales" (Welsh Government, 2012a, p. 24). It can be posited that the quality of the relationships between the two governments would be influential in aligning market creation mechanisms. Furthermore, with a high level of relational social capital or trust it would be possible to introduce the latitude for regional policy makers to create the most effective regional framework to support both innovation and transition (Coenen et al., 2015).

However, in scoping conversations with WG officials, it became apparent that the influence the WG had on the ROC levels was limited. Whilst recommendations were made to institute changes to the ROC levels, it was not possible for WG officials to ascertain the degree of influence on the final decision. The territorial alignment between these two levels of government is crucial for development within the region. The evidence suggests WG has limited influence over the electricity market to thereby encourage market creation. This evidence contributes to a growing narrative that devolved governments do not have a significant role in shaping the UK electricity market, compared to major corporate actors (Toke and Nielsen, 2015; Kern et al., 2014).

ROCs were criticised for their lack of efficacy in steering the renewable energy market, especially in relation to innovation, because they did not “reduce risk for investors but instead emphasised competition between technologies in an attempt to minimise costs to consumers” (Woodman and Mitchell, 2011, p.3914). In 2011 the closure of the scheme to new generators from March 2017 was announced, but assurances were provided that accredited electricity would receive full lifetime support of 20 years until scheme closure in 2037.

5.2.3 Contract for Difference

To replace the ROC the UK Government developed an auction-based system, Contract for Difference (CfD), to fund new RE contributions to the grid. CfDs were devised to protect developers of projects with high upfront cost from the volatility of the wholesale energy market price and to minimise costs to consumers (BEIS, 2020). In effect, CfDs are the guarantee of electricity price; the generator is supplemented when the market value is below the ‘strike price’ and generators pay back the consumer when the market value exceeds the strike price.

The CfDs were announced in rounds: round 1 of CfDs commenced in October 2014 – March 2015, round 2 March – September 2017 and round 3 May - November 2019. The experience of technology developers in Wales (TD4, TD5) was that the provision of these contracts in rounds posed a risk due to the 18 – 24 months between the closing of one round and the opening of another. This highlights one of the many temporal aspects that must be negotiated by innovators when creating new technology, these gaps can be difficult to negotiate for transition where windows of opportunity may open and close in the interim. Those developers that secure CfDs enter a private law contract with the Low Carbon Contracts Company which is UK Government owned. The contracts are held publicly on the UK Government website. However, for many of the technology developers, the change in the electricity pricing system for renewables was a source of design uncertainty.

> "So that means a lot of the devices were over-engineered for how long you would have them in the water. So, it's interesting (the change from ROC to CfD). Most (developers) are developing to a revenue stream, it must be quite frustrating as an industry, because you want that certainty." (SC1)

Devices had been developed with a view to operating for twenty to twenty-five years in line with ROC criteria, yet CfDs for RETs operate for fifteen years. Further adding to inequality between technologies, CfD for new nuclear runs for thirty-five years (Policy Exchange, 2017). This form of technology-neutral initiative would be more suitable for when RETs have matured, with renewable generators still at market risk in comparison to nuclear (Skea et al., 2011). The inability of ME developers to compete for lease and the strike price agreed for offshore wind is a risk to wave and tidal, where developers might go to other countries for more attractive financial packages (Energy Voice, 2019). This highlights a misalignment between innovation and transition mechanisms, the UK Government is seeking to progress market creation mechanisms for RETs that are at a higher technology readiness level, but in doing so jeopardise developments in the pre-commercialisation niche technology such as ME. However, for transition to be successful, arguably there is a need to have a range of technology options and large-scale ME is credited with the potential to outperform nuclear when whole of life cost is accounted for (Hendry Review, 2016).

5.2.4 Evaluation of electricity market pricing

It is difficult to ascertain how far ROC levels influenced ME developers favouring Scotland as a location over Wales, but it is important to note that Scotland had a significant level of infrastructure to support ME technology development. The 'world leading' European Marine Energy Centre (EMEC) in Orkney was established in 2003, providing extensive wave and tidal testing facilities. An industry-led Marine Energy Group devised a report in 2004 entitled 'Harnessing Scotland's Marine Energy Potential'. These two factors alone highlight the long-standing, wide-ranging and proactive stance the Scottish Government took to encouraging MEI development. With respect to regional characteristics, this infrastructure and outward-facing attitude to ME could be theorised as likely to attract developers to a region as greater market creation certainty would be beneficial to innovators.

ME was directly addressed by WG first in 2011. Supply chain interviewees considered that WG had not been sufficiently proactive in supporting industry development. WG were thought to have "been saying the right things for years, but there's not really been any substance behind it" (SC8). It could be inferred from the activities in Scotland that offering a range of support mechanisms outside of electricity price for market creation is of importance. In particular, the establishment of testing facilities and their contribution to technology embedding receive further consideration in Chapter 7. Conversely to Scotland, it can be summarised that limited action has been undertaken to render the region attractive to developers with respect to the timing of policy statements and other non-financial incentives.

With respect to the role of regional characteristics, it can be concluded that the capacity of a government to institute other mechanisms to encourage market creation is also important. Scotland is classed as a 'transition region' by the EU (pre-Brexit) and cannot be considered less-developed. Alongside the ROC and CfDs, the Scottish Government provided additional support for ME electricity price with the 'Wave and Tidal Energy Support scheme'. This scheme provided a 40% capital grant for qualifying projects and an enhanced payment of 10p per kilowatt-hour in addition to the ROC payment. This suggests an additional capacity to employ market creation mechanisms.

Across the UK, it would appear that CfD has not been a successful tool for wave and tidal technology, seemingly favouring offshore wind which could be considered an incremental innovation. Both ROCs and CfDs are designed with cost to the consumer in mind, providing a greater level of support to devices at a higher technology readiness. Due to the management of CfD payments, more demands are placed on developers to fulfil tasks outside of innovation. With a daily accounting system for CfDs:

> "you would get 365 payments that you have to trace, with payments at different times. For developers that are in reality groups of engineers it is an administrative nightmare. And you have to get to the point of being a big enough project in the first place" (SC1).

In all, it could be summarised that market creation through electricity pricing mechanisms has had mixed success. In Wales it could be argued that ROC and CfD have not successfully encouraged the market – only one device was allocated ROCs (TD4 which has subsequently disbanded), and CfDs to date have favoured well-advanced technologies. The change from ROCs to CfD was a disjointed approach, changing the requirements of the technology, signifying ill-used resources for developers. Furthermore, the offering of funding in rounds introduces a temporal challenge to innovation planning.

Private investment and the benefits of mixed source funding to support innovation will be considered in Chapter 6. However, the other avenue through which the UK Government shapes the risks and opportunities facing the RE industry is through its consenting process. In particular, the seabed which provides the end location for this technology – and in effect allocates access to the resource - is managed by the Crown Estate (CE) and its influence on industry transition will now be considered.

5.3 The Crown Estate (CE) and seabed consents

Alongside the electricity market pricing, consenting processes can be a particular stumbling block. TD4 experienced significant time delays on the pathway to power generation which was said to have ultimately contributed to the disbanding of the company (rather than the failure of the technology itself). These inter-related market mechanisms of securing a locale to generate energy and the price this electricity commands are not devolved powers. This means that the influences of these measures are relatively uniform across the regions of the UK and potentially not attuned to less-developed regions. Within Wales this means that the WG struggles to exert agency which aligns technology development and regional priorities. Consenting factors will now be evaluated in the context of the pre-commercialisation stage of the MEI.

The Crown Estate (CE) was established by statute in 1760 and belongs to the reigning monarch. Operating under the Crown Estate Act of 1961 it is an independent organisation that is controlled by a Board. The CE manages the land of the Crown amounting to £14.3 billion in real estate business, with the duty to maintain and enhance the value of its interests. Surplus revenue is returned to the Treasury who act as the principal Governmental stakeholder. Managed by a team of around 450 people, CE has interest in central London, offshore wind, rural and coastal locations, and the seabed around England, Wales and Northern Ireland. A team of around forty engage with the wider marine sector.

Developers obtain a seabed lease from the CE. Beginning with an 'agreement for lease', this gives the developer an option over the seabed where they can undertake surveys and deploy monitoring equipment.

> "It's important for developers to have the agreements as it means that they can plan how they would operate in a specific site without worrying that their patch of grass will be stolen". (GV2)

Construction, development, and exercise of the option by the developer are only possible once conditions are satisfied and the CE grants a lease of the seabed. If conditions cannot be met then the option will lapse, making the section of the seabed available to other developers. An interviewee highlighted that as the landowner, CE's technology siting decisions are crucial.

> "The buck stops ultimately with them (CE), or conversely, they're the first part of the process – before a developer can do anything".

The consenting process is subject to a range of legal obligations on land and at sea. Alongside these legal consents, an Environmental Impact Assessment is required for the proposed site of the technology, which, according to an interviewee that works in a statutory environment, “arrive in the office on a pallet” (GV2). As a result, developers must undertake extensive modelling and monitoring to establish the impacts of the device on the locale and the natural environment. This highlights the wide range of legislative demands within the consenting process that developers must have the capability to engage with outside of device design.

The range of activities undertaken by the CE are funded by “one pot of capital” (GV1), where the profits of high value central London property puts CE in a position to “take a risk” (GV1) on the MEI. Further, the marine environment is protected by the Marine and Coastal Access Act (2009), mandating CE performance or “Parliament will say we’re not doing our job” (GV1). With limited stakeholder pressure that is not subject to political cycles, the CE is able to make longer-term decisions with respect to ME as “the resource is not going to go away, the energy need is not going to go away...it’s very advantageous.” (GV1)

The CE’s marine team must be mindful of competition laws as “monopoly owners” of the seabed (GV1). UK-wide leasing rounds for locations have been used to navigate this monopoly as individual granting of agreements for lease would be contrary to competition law. However, much like the CfD rounds, developers highlighted that this was a possible cause of delays within the development of the technology. This highlights emerging evidence that there are many temporal aspects that developers must address and co-ordinate, alongside the spatial and technological.

Investment in the MEI does introduce a vulnerability for the CE, as should the Government decide not to “subsidise the industry...we’ve got no tenants”. It could therefore be surmised that spreading activities across a few industries and seizing the opportunities presented by offshore wind make sound development strategies. In this instance, the CE’s remit of making profitable returns coupled with the different site requirements of offshore wind make it likely that developments in this technology could co-exist with wave and tidal development. As indicated by the CE interview, the longevity of the institution is not at risk, "we run our own business, as long as we do it properly, we're not like DEFRA for example wondering if it'll continue to exist or have its budget cut." This suggests the competing pressures for some organisations, who must make policy in light of potential future budgetary changes. Importantly for transition, this puts CE in a position to support the development of the ME by providing direct intervention to reduce risks in the consenting process. The stability experienced by this organisation that forms part of the landscape allows the counterbalancing of the instability that is experienced by an actor in the niche. This then means that the CE can focus on the 'pull' element of transition by contributing to market creation.

A technology developer outlined that the management of the interaction with CE for the conditions for agreement and lease is complex and "more than a full-time job" (TD1). This is due to the necessity of providing a full works methods statement and a decommissioning plan. The introduction of a general template in 2015 made this process more difficult as it is not always navigable for those that are new to the process.

> "So if we're thinking of a developer managing a grant and relationships with CE then we can see this is going to exclude a lot of technology. You need to think about the time that is being taken up in the margins of the innovation. Also, when you couple this with maybe the difficulty of getting private funding, this becomes increasingly complex." (TD4)

The risk introduced with the extent and cost of evidence required of developers before marine devices become consented by the CE has been highlighted. However, to address this, the CE announced the development of demonstration zones in 2014 throughout the UK where pre-consented seabed rights could be utilised by technology developers. The demonstration zones make a significant contribution to technology embedding mechanisms, but the overall de-risking of the consenting process for developers in the early stages of testing also contributes to market creation.

A statutory interviewee commented that CE does not necessarily have a clear steer from the UK Government and are “often making policy the Government should be doing” (GV2). This suggests a tension between the market mechanisms enacted by the UK Government and the support of MEI development across the UK. Seabed consents are a significant part of the embedding process but could be subject to competing pressures on the marine space as exemplified by the range of licences and notifications for the use of the waterways. This agency on the part of the CE to influence industry development and the time frames for managing these competing pressures can introduce significant capital cost risks. It is therefore important for a developer to secure a licence, but these developers must also be in the position to engage with the complex legislative process, highlighting the range of skills needed. Questions therefore remain as to what extent the complexities of siting and licencing can be ‘fixed’ away from ME developers in order to further support industry transition.

The complexity of the devolved consenting system and the delicate nature of relationships between some of the key actors emerges from the evidence. In Wales, the CE works directly with NRW who want “a leasing decision to consider environmental issues, but from the perspective of CE they want to be maximising returns” (GV2). The evidence suggests that the balance of power in market mechanisms in Wales is in favour of the CE due to the seabed rights yet “the burden of the consenting process” is passed to NRW. This provides some insight into the nature of the relationship between NRW and CE, where there is a collaborative ethos to generate a supportive environment that contributes to market creation. The quality of the relationship between these institutions can be considered important in easing transition processes and suggested to be lacking between the UK and Welsh governments, thereby hampering innovation. The institutions within Wales and further detail on the work of NRW within the framework of CE mechanisms will be considered next.

5.4 Welsh Government implementing UK Government governance

5.4.1 Overview

As a result of devolution, the WG operates at multiple levels and could be considered to have two identities: lower tier government actor enacting UK Government policies, and that of policymaker within devolved areas of power. The WG is charged with the fulfilment of UK policy and the development of devolved Welsh policy. This presents several inter-related opportunities and challenges. Where the WG does not have legislative power, it is possible that in the areas of devolved control it can undertake activities to compensate for UK Government policies that do not fit regional needs. This section evaluates how the WG fulfils the role of a lower tier government body.

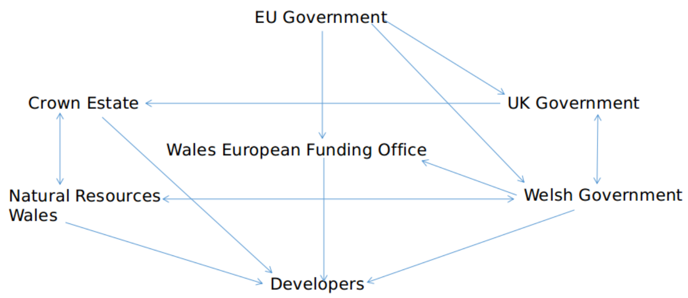


Figure 5.1. Institutional relationships in the MEIW before Brexit.

Source: Author's Own.

The day-to-day implementation and monitoring of the MEI is not undertaken by the WG and is carried out by other bodies such as Natural Resources Wales (NRW) for consenting and Wales European Funding Office (WEFO) for the administration of grants. The web of connections between these governmental actors is set out in Figure 5.1.

The number of actors introduces the opportunity for a range of market creation mechanisms to be utilised and prioritised, creating a complex framework. At the same time, there are power exchanges between the actors. The arrows in Figure 5.1 provide an insight into the relationships within the MEIW, highlighting the direction of influence between actors.

Whilst the Wales Act 2017 did devolve further energy-related powers, the transfer of power has not been in step with that which was offered to Scotland. This could be a further sign of the lack of capacity on the part of the WG to influence the policies of central government. Indeed, the dialogue around the Swansea Bay Tidal Lagoon perhaps best demonstrates the limits of WG's legislative and fiscal power. The project has been identified as a great opportunity for Wales, yet the WG did not possess the legislative ability to consent the project nor the fiscal ability to fund it.

Further, an 'Institute of Welsh Affairs' report 'Funding Renewable Energy Projects in Wales', called on the WG to lobby the UK Government for future access to the CfD for onshore wind. In response, the Welsh Government (2017) details:

> "The Cabinet Secretary for Environmental and Rural Affairs has already written three times (September and November 2016 and July 2017) to the Secretary of State for Business, Energy and Industrial Strategy highlighting her concerns in relation to the Contract for Difference regime".

The issuing of three letters suggests that attempts to exert effort had little effect. Questions as to the ability of the WG to influence the UK Government has some history in Wales, where examples from the wind energy industry are numerous (Cowell, 2017). As of early 2020, onshore wind will be included in the CfD contract round to take place in 2021, but it is not within the scope of this project to ascertain the extent to which this is as a result of WG lobbying.

Figure 5.1 particularly highlights developers' required institutional knowledge and capacity to support multiple institutional relationships. Interviewees frequently criticised how the WG have managed ME, with frequent change of minister and civil servant department responsible for industry oversight. This has come as a result of energy being moved between departments and different portfolio representation. A developer highlighted that following a decade of operating within Wales, “we’re never clear who the best person is to speak to in WG.”

This has implications for developers, who must negotiate this institutional set up and foster relationships, with social capital demonstrated to be a key factor in innovation. The benefit of a country the size of Wales anecdotally has been the ability to communicate easily with governmental actors (TD4), yet the evidence highlights a seeming absence of quality in many of the relationships between key institutional bodies. The range of priorities encouraged by the governmental actors in Wales would make it seem necessary to have an actor that balances these demands to develop the MEI. The following section considers the work of Natural Resources Wales in this regard.

5.4.2 Natural Resources Wales (NRW) and environmental consents

With a budget of £180million and 1,900 staff across Wales, Natural Resources Wales (NRW) is the largest WG-sponsored body. Formed in 2013, it is an amalgamation of the functions of the ‘Countryside Council for Wales’, ‘Forestry Commission Wales’, and the ‘Environment Agency in Wales’. Responsible for forty different types of regulatory regime it has many roles and a ‘Remit Letter’ from the WG sets out yearly goals. The body has climate change mitigation at its core that has been driven by the UK Government’s 80% by 2050 goal and the WG goal of 3% reduction in greenhouse gas emissions year-on-year from 2011 onwards. Within the MEIW, the NRW is the principal government actor that directly interacts with developers and the industry. NRW has the responsibility for twelve nautical miles from the coastline, which “nearly doubles the size of Wales” (NRW Website).

Legislatively, The Environment (Wales) Act 2016 and the Well-being of Future Generations (Wales) Act 2015 create the framework within which NRW operate to manage Welsh natural resources for socioeconomic and environmental purposes. The NRW has a dual role in relation to MEIW - regulator and advisor, seeking to work in a responsive manner outside the traditional regulatory approach (GV2). An individual who had worked at Countryside

Council for Wales and NRW commented on the evolution within the institution's advisory role from nature conservation to sustainable development.

> "Previously with Countryside Council for Wales it was easy to say, "it's likely to have environmental impacts, you can't do that, no." That was seen as a real hurdle for development. Now we've got this sustainable development remit it's not acceptable really to say absolutely no way because we don't understand the impacts. It's more about facilitating and searching for solutions rather than saying no, that's a problem." (GV2)

This evolution in ethos was also noted by the developers, where the practices of the Countryside Council for Wales had been found to constrain industry progression. This is part of a wider institutional change, where previous decisions by the Countryside Council for Wales were reversed by NRW to permit a motor racing circuit (BBC, 2014b). Further, the NRW are aware that consenting uncertainty could stall private investment in the MEIW (GV2). This evidence shows the NRW's awareness of their role in supporting market creation and provides insight into how the goals of any one actor can significantly influence the development of a technology trajectory.

The evidence suggests that NRW could be considered to internalise responsibility for striking a balance between competing imperatives. In its relationship with CE, NRW moderates the balance between 'most competitive' technology and environmental monitoring concerns. NRW's relationship with the WG balances 'most jobs' with environmental concerns and is increasingly becoming less precautionary. This shows the mediating role adopted by this institution to manage relationships between actors and support the development of the MEIW. The organisation is aware that consenting is:

> "A lynchpin in the whole getting stuff in the water process, unless developers can successfully navigate environmental legislation, they're not going to get anything in the water. With all the financing, and infrastructure, and supply chain in the world, unless they can get those consents and tick those boxes they're not going to get

anywhere" (GV2).

The centrality of this challenge is echoed by developers, where TD4 highlighted that in the afterlife of the technology, the potential purchaser is not particularly interested in the IP as they are likely to have their own technology. What the purchaser would be interested in is that the disbanded technology developer had a site accredited for ROCs and the accompanying years of animal monitoring and survey work. This suggests that to promote and embed ME in the region there is a likelihood that de-risked sites will become more important than local technological development. It is unclear whether this high scrutiny for environmental data relates solely to the nascent stage of ME technology or that many parts of the Welsh Coast are subject to protective legislation. GV2 and TD4 undertook extensive monitoring which the developer estimated to have become too substantial a task alongside the innovation process. This shows the challenge of developing a breakthrough innovation within a framework that requires reconfiguration to accommodate the technology type. As such, NRW seems to adopt an intermediation role between innovation and transition mechanisms.

NRW's energy roles and remit fall across several teams and directorates, this lack of unified department is potentially problematic with regards to a joined-up approach and the building of quality working relationships with a high level of social capital between the NRW and developers. However, in practice it is a small number of individuals who interact with the industry, attending the Working Group meetings of MEP and MEW, and presenting at the annual industry conferences. The NRW interviewee stated that the reason for this was to ensure early engagement with developers, building the types of relationship that encourages discreet conversations, this is evidence of both structural and relational social capital. The experience of the interviewee was that a short in-person interaction can negate multiple emails or phone calls (GV2). Further, it is efficient for NRW as they keep the developers abreast of changes, communicating informally and answering questions as they arise. There is also the benefit of an "evolving conversation with developers while they refine their ideas" (GV2), allowing possible issues to be dealt with early. This evidence all points to the value of social capital for NRW to support industry development and maximise the efficacy of the mechanisms the organisation seeks to utilise.

Significantly, NRW are aiming to be more flexible in relation to potential environmental risks, and this is particularly relevant in the ME sector as the environmental impact of devices is difficult to ascertain until the technology “gets wet” (GV2). At the same time, this technology cannot obtain consent without regulators knowing its impact. This is where being “pragmatic” and “proportionate” (GV2) in the treatment of ME technology is important to the NRW, as it could stall the market. If there is uncertainty around consenting, “investors aren’t going to invest into a project if they know there’s a big risk in terms of getting the permissions, they need to get their device going” (GV2). This shows a cognisance of NRW’s pivotal role as an actor in Wales in enabling market creation mechanisms.

Significantly, the different device types carry different environmental and animal risks, meaning that it is more difficult to share learning across the technologies. This suggests another potential brake on industry development, where technological diversity may adversely impact other aspects of the pre-commercialisation path. The interviewee highlighted the further benefit of the semantic change from “are the animals there” which as part of Countryside Council for Wales would have been sufficient to halt consenting, to “what do they do there? Are they feeding? Lost?” (GV2). The established practices of the Countryside Council for Wales to ask for significant amounts of data is no longer viewed as “proportionate or acceptable” (GV2). The new method of monitoring seeks to establish categories of animal and environmental vulnerabilities that could then be applied to the technology consenting process.

However, each stage of research and development that is undertaken by a developer is beneficial to the NRW. The NRW interviewee outlined that the environmental monitoring affiliated with each device feeds into a growing evidence base and outlines the importance of knowledge sharing between actors in an industry. This perhaps can be better achieved at the local scale due to higher levels of trust, the regularity of interactions, and the building of knowledge networks. Importantly in the transition process, this shows how the generation of marine environment knowledge co-evolves with the progression of technology. Whilst the NRW is the actor in the MEIW singularly most concerned about animal interaction with devices, efforts are made to balance these concerns with learning. This perhaps runs counter to the risk-cautious stance of many of the other institutions within the MEI. The evidence indicates that NRW is aware that should a high burden of proof of 'no adverse effect' be placed on developers, the industry will be damaged.

Essentially, this is a period of exploration and experimentation for a governing body such as NRW. Marine Energy Scotland is also trialling methods. The two regulatory bodies share knowledge about how best to monitor the environmental impact of these technologies, highlighting NRW's openness to maintaining a diverse knowledge network. In this sense the market element within consenting that NRW is seeking to prioritise is the creation of economic sites that satisfy CE and WG requirements, regional characteristics that will support transition. To do this, NRW mediates its demands to apply proportionality to historical standards and processes. What is notable to the NRW interviewee is that the ME sector "does seem to be one that is willing to explore all those avenues and try and work together to come up with the most sensible option." This further highlights the importance of maintaining knowledge network structures and a collaborative ethos. The cost implications of these processes for developers are notable and will be discussed further in Chapter 6.

Cost issues are also relevant for NRW, who at the time of interview in 2018 were developing a charging system for the advisory role undertaken and forewarning the industry of its introduction. After the first two hours, pre-application information will be charged at a rate of £125 per hour, this includes information relating to siting and other factors. Developers will continue to be responsible for bearing the cost of instituting environmental monitoring processes. The charging system will be introduced in April 2021 across all functions, not just energy or marine consenting.

The NRW interviewee was concerned that this new system would have a significant impact on the MEI; they considered that the charge would simply push the valued pre-application conversation to the application stage (GV2). This would mean “a lot of projects proceeding through to consent with little input from us” (GV2), at this stage issues would be more difficult to iron out and “could cripple” the developer. Charging for services contributes 20% of NRW’s total funding, it could be concluded that diminishing public funding impacts the services that are offered as the NRW seeks to “reduce the burden on the public purse” (GV2). This in turn will have an impact on the development of the MEIW and further adds to the ‘first mover advantage’ that has been enjoyed by solar photovoltaic and wind.

5.4.3 Interim evaluation multi-level governance enactment

The evidence thus far highlights the flow of influence between institutions and the framework of consenting processes within the MEI. CE is responsible for consenting processes on behalf of the UK Government and NRW is responsible for consenting processes for the WG. Interestingly, due to the differing remits of these bodies, different market pressures are exerted. CE seeks to maximise seabed rents but takes a longer view on the profitability of the MEI. NRW seeks to internalise the different imperatives placed on the MEI but austerity has established a need to charge for services offered, impacting the capital available for developers to invest.

It would seem, therefore that multi-level governance characterises the system, with layers of power and relationship between the governments and the organisations that operationalise different goals. Contrary to the established hypothesis there is limited evidence of a high level of engagement on the part of the WG to render the region attractive to developers with respect to market creation processes. Further, the flow of influence between the UK Government and WG focuses on a top-down process where UK Government retains control of the main market creation mechanisms. The key factor to balancing the demands placed on developers is the collaborative relationship between the CE and NRW, highlighted in several of the interviews with the MEIW. Through joint working that is supported by strong social capital between the organisations, the mechanisms utilised are compatible, thereby simplifying the consenting process significantly. The NRW interviewee highlighted that developers initially interact with the CE; the organisation's filtering processes should ensure that no unviable technology applications are passed to NRW. Through working together, it would be possible to maximise the outcome "from the 'box-ticking' that the CE have to do" (GV2).

Following the investigation of the relationship between different UK Government and WG institutions and the WG's role as a lower tier government actor, the analysis now turns to consider how the WG seeks to steer the MEIW. This includes the enactment of policy and any other activities undertaken to mitigate UK Government measures considered to stall the industry in Wales.

5.5 Devolved market creation mechanisms

5.5.1 Introduction

Within its role as a policy making institution, the WG has many levers at its disposal to foster market creation. These measures can navigate the structure set out by the UK Government, particularly in respect to the WG's responsibilities for consenting. As highlighted above, the extent to which WG can engage in market creation is limited by a lack of power over electricity pricing and seabed siting decisions. As such, as a policymaker the WG must then seek to create stable conditions for the market but cannot create the market. The mechanisms that are then available to the WG range from direct policy to the support of exercises aimed at knowledge gathering. This section will first highlight the timeline of key policies related to the MEI, then the dominant themes of these policies will be elaborated. The final governance consideration will be the support of knowledge gathering initiatives to better define the needs of the industry.

5.5.2 Policy timeline

Exploration of WG and UK Government policies serves a dual purpose of setting the policy context and providing an analysis of its impact on the MEI transition in Wales. Policies here refer to published strategies that set out the expectations of the Government. Table 5.2 highlights the chronology of a decade of UK and Welsh energy-related policy (Appendix F). In the Welsh context, key themes that emerge from the analysis were nuances in influencing the technology trajectory, economic growth goals, and comparison with other RETs. Grant funding was also a significant theme that will be considered in the Chapter 7 for its support of innovation and technology development.

Year	Title	Government
2019	Prosperity for All: A Low Carbon Wales	Wales
2016	Hendry Review	UK
2015	Wave and Tidal Energy in the UK: Capitalising on Capability	UK
2014	Marine energy technology roadmap 2014	UK
2014	Wave and Tidal Enabling Actions Report	UK
2014	Maximising the Value of Marine Energy to the UK	UK
2013	UK renewable energy roadmap (update)	UK
2012	UK renewable energy roadmap (update)	UK
2012	Technology innovation needs assessment (TINA) marine	UK
2012	UK Wave and Tidal Key Resource Areas	UK
2012c	Energy Wales: A Low Carbon Transition	Wales
2012b	Energy Policy and Planning in Wales	Wales
2012a	Marine Energy Infrastructure Study	Wales
2011	UK renewable energy roadmap	UK
2011	Marine Renewable Energy Strategic Framework	Wales
2010b	Marine energy technology roadmap	UK
2010a	Marine energy action plan 2010	UK
2010	A Low Carbon Revolution - The WAG Energy Policy Statement	Wales
2009b	The UK renewable energy strategy	UK
2009a	The UK low carbon transition plan: national strategy for climate & energy	UK
2009	Capturing the potential - A green jobs strategy for Wales	Wales

Table 5.2. Decade of policy documents analysed.

Source: Author's own.

5.5.3 Influencing the technology trajectory

A societal function such as energy can be influenced by institutions for different technology trajectory objectives, such as energy security or the creation of a market. Energy security is not a dominant feature of Welsh policy but is prominent in UK policy and is a legitimating discourse. This is attributable to the need for the UK Government to ensure security and affordability of electricity supply (Kuzemko et al., 2016).

The Welsh framing of the energy trajectory cites that declining fossil fuel availability would create higher prices and affect equity of access. Energy efficiency has therefore been a policy focus to "make producing the majority of the energy we need from low carbon sources more feasible and less costly" (Welsh Assembly Government, 2011, p.5). Alongside carbon reduction, energy efficiency has economic implications including an impact on fuel poverty, which is a particular issue in Wales. The end goal, however, is to "promote Wales' position as a low carbon nation with greater resilience against fuel supply interruptions or price increases" (Welsh Government, 2010, p.18). This framework of energy security is not consistent within the WG policies, as a limited number of technologies are favoured, typically of a large scale that are under UK Government consent.

The creation of a marketplace for RETs ensures that there is future income so that a project can source capital funding (Welsh Government, 2012c). However, much of the work in market formation is leveraged through the UK Government's ROCs, CfDs, and Electricity Market Reform. Scotland has made great inroads to developing ME by utilising its differentiated power with ROCs to its advantage, supported by very public Scottish Government advocacy for the industry (Jeffrey et al., 2013). Unlike Scotland, however, Welsh policy gives a stronger imperative to what the industry has to offer the country. Alongside economic returns, Welsh policy asserts that the community benefits of RETs must be secured by the region and that "the current energy system results in significant economic leakage from Wales" (Welsh Government, 2019, p.12). This reinforces the agenda by which RETs and ME technology development is approached in Wales – that primary interest lies in economic growth potential rather than carbon reduction through innovative technologies, a theme which recurs in subsequent parts of the analysis. This can also be interpreted as a regional characteristic that will influence sustainability transition as the WG is undertaking action in the context of the prevailing socioeconomic conditions.

UK Government policy recognises that a wide range of deployment scenarios means that market uncertainty is being experienced globally due to demand uncertainty, infrastructure conditions, insufficient payback on early-stage R&D and insufficient collaboration and knowledge sharing (Low Carbon Innovation Co-ordination Group, 2012). However, the UK is "uniquely well positioned" (Low Carbon Innovation Co-ordination Group, 2012, p.1) and could potentially capture a market share of around 15% of global ME resources. The dominance of UK ME device developers is recognised as an opportunity and aligns with WG policy that seeks to focus on comparative advantage in Wales to quickly develop the relevant skills base to compete in the global marketplace. In this respect, the goals of the UK Government and WG align, potentially providing greater impetus to the transition process.

The competition between technologies and disparity of support is evident throughout the policies, where the UK Government and WG favour large devices to those that are smaller and modular. Nuclear as a low carbon technology is consistently promoted and within the field of ME technology itself, comparison of technologies based on their potential for growth and employment dominate. In Wales, the policy focus in 2019 remained on "the lowest cost technologies, as recommended by the UKCCC and a range of other industry sources, in order to keep the cost of energy bills down" (Welsh Government, 2019, p.75) , showing a prevailing adherence to existing policy strategies over the pursuit of innovation benefits. The next section will discuss this focus on low-cost growth within policies and the impact on the ME transition within Wales.

5.5.4 Growth imperatives

With a focus on carbon reduction, creating expectations and signifying commitment, UK Government policy also recognises the “once-in-a-lifetime opportunity” (UK Government, 2014c, p.1) that ME presents for employment and export benefits. Some policies model the export and job potential, creating an estimated £1-4bn in GDP by 2050 (Low Carbon Innovation Co-ordination Group, 2012). Knowledge sharing of scoping, licensing and consenting of first array learning through consultancy is also identified as a “bankable know-how” that can be exported to global markets (UK Government, 2014c, p.6).

Employment figures in UK Government policies are not broken down by sector or country. ‘Energy Wales: A Low Carbon Transition’ (2012) outlines that Wales stands to “generate far more than a proportional share of these new jobs” (p.6). As a result of the industrial decline in Wales, the need for jobs and growth created through RETs dominates the Welsh agenda. There is only one WG policy (2011) that does not refer to growth potential which is the ‘Marine Renewable Energy Strategic Framework’ (MRESF). It could therefore be suggested that there is a high level of adherence to growth principles within Welsh policy, with aims that focus on the economic rather than the environmental. It seems likely that this is driven by the regional characteristic of a less-developed economic status, with decisions made in the context of resolving issues in the short-term.

This identified growth potential is commonly credited to nuclear power stations and tidal lagoons. However, a WG commissioned report, ‘The Economic Impact of the Development of Marine Energy in Wales, 2013’ modelled the impact of differing combinations of wave and tidal technology. Notably, the analysis highlighted that with more installed megawatt capacity the number of full-time employees reduces as a ratio of total capital investment (Table 5.3), as does the GVA (Table 5.4). This evidence suggests a tension between the ‘quick wins’ of one large-scale technology against the potential of multiple technological designs operating in arrays.

	Scenario 1 - 60MW			Scenario 2 - 300MW			Scenario 3 - 1GW		
	Tidal	Wave	Total	Tidal	Wave	Total	Tidal	Wave	Total
Manufacturing & Energy	370	310	680	2,250	580	2,830	5,500	2,000	7,500
Construction & Maintenance	340	350	690	2,310	630	2,940	6,260	2,520	8,780
Distribution, transport & comms	120	100	220	760	180	940	1,960	670	2,630
Professional & Public Services	230	210	440	1,420	380	1,800	3,430	1,420	4,850
Total	**1,060**	**970**	**2,030**	**6,740**	**1,770**	**8,510**	**17,150**	**6,610**	**23,760**
FTE/MW	35	32	34	28	30	28	23	26	24

Table 5.3. Economic Impact of the Development of Marine Energy in Wales: Development and Installation (Person-Years of Employment).

Source: Regeneris, 2013, p.56

	Scenario 1 - 60MW			Scenario 2 - 300MW			Scenario 3 - 1GW		
	Tidal	Wave	Total	Tidal	Wave	Total	Tidal	Wave	Total
Manufacturing & Energy	16	14	30	98	25	123	240	87	327
Construction & Maintenance	8	8	16	56	15	71	152	61	213
Distribution, transport & comms	5	4	9	35	7	42	91	28	118
Professional & Public Services	9	8	17	52	14	67	128	53	181
Total	**38**	**34**	**72**	**241**	**62**	**303**	**611**	**229**	**840**
GVA/MW (£m)	*1.28*	*1.13*	*1.20*	*1.01*	*1.03*	*1.01*	*0.81*	*0.91*	*0.84*

Table 5.4. Economic Impact of the Development of Marine Energy in Wales: Development and Installation (Gross Value Added, £m 2013/14 prices).

Source: Regeneris, 2013, p.55

The preoccupation with growth does not wane throughout the WG policies, with the 2019 'Prosperity for all: A Low Carbon Wales' introducing joined-up policymaking for carbon reduction. With 100 policies and proposals across Ministerial portfolios it could be considered an important driver for change. The next section will consider whether the WG does seek to better understand and address the management of the MEI through initiatives that promote knowledge sharing amongst governance institutions, with the end goal of creating effective market creation mechanisms.

5.6 Knowledge acquisition activities

5.6.1 Offshore Renewables Joint Industry Programme (ORJIP) Ocean Energy

ORJIP Ocean Energy is a UK-wide programme that enables collaboration between CE, Marine Scotland, WG, Scottish Natural Heritage, NRW, and Crown Estate Scotland. In 2013 there was recognition that a strategic approach would help de-risk the consenting of marine energy projects in the UK, and this led to the formation of the Offshore Renewables Joint Industry Programme (ORJIP) Ocean Energy. SC4, a significant actor in the development of ME in Orkney and increasingly Wales, was commissioned by CE to undertake a desk study whose draft report was discussed by around fifty stakeholders at a workshop. The findings of this report prompted the joint funding of a Secretariat to run ORJIP Ocean Energy for a 15month pilot phase. This produced a prioritised list of major research issues and the programme continues to operate.

> "Coming from our own perspectives we all had different ideas what those uncertainties [in the MEI] were, but having that initiative to reach a consensus across the UK was a massive step forward" (GV2).

Members of ORJIP Ocean Energy can initiate, fund, procure, and manage research projects. A number of these organisations are present in Wales and this shows an important source of knowledge sharing with governmental actors such as CE and NRW who can use their networks to draw knowledge from other regions. Projects are explored collectively, with any data gathered open access and links are made to other relevant studies. This is an interesting compendium of industry knowledge related to the environmental risks and is a very good indicator of collaborative market creation mechanisms.

The NRW interviewee highlighted that some of the gaps identified were not unique to ME and dealt with in other industries. Understanding the responses of other industries helps establish whether these gaps “will make a material difference on the outcome of the consenting process”. This shows an awareness of different sources of knowledge and the benefits of utilising learning from other technological trajectories. Whilst not a WG or UK Government initiative, membership of this programme shows a commitment to multiple methods of encouraging industry development and the creation of a marketplace.

Whilst this group addresses many of the broader issues within the MEI, WG initiated a further initiative, a 'Task and Finish' group to better identify the requirements of the Welsh MEI and is the subject of the next section.

5.6.2 Task and Finish Group

A 'Task and finish' group was set up in 2015 "to advise the Minister on a sustainable approach to deliver jobs, growth and wealth from the emerging marine energy sector" (final report, p. ii). The findings were published in the 'Marine Energy Task & Finish Group (2016) Marine Energy Plan for Wales – Unlocking the Energy in Our Seas' report (final report). Following the drafting of this final report, the group was disbanded with the WG committing to working with the industry to progress the findings. The group consisted of six industry actors, two were developers. One developer was TD4 and the other the company behind the Swansea Bay Tidal Lagoon.

The final report was presented as a plan that summarises progress to date and suggests future actions around the topics of political leadership, jobs and growth, finance and funding, research and development, consenting and leasing, and infrastructure. The report positions the existing supply chain in Wales and the history of the oil, gas, and steel industry as factors that would aid industry development. To some extent this aligns with the theory that less-developed regions will seek to continue in the path of existing knowledge (Aarset and Jakobsen, 2015). Further, it suggests that the region will have an advantage in engaging with this new technology, a persuasive power for support. This said, the cross capabilities found in the existing industry are wide ranging and could support sustainable employment opportunities in Welsh coastal regions, contributing to both innovation support and embedding mechanisms.

The Task and Finish Group make clear the potential of an indigenous industry with high commercial reward, but the report disproportionately references tidal lagoon technology. This is perhaps due to group membership or that the assumed higher technology readiness level makes commercial return more immediate, with the position of the technology within the niche influencing perceptions. The lagoon focus could be argued to further reinforce the dominance of the 'big technology' narrative in Wales, crowding out smaller technologies. Yet steps are taken towards path creation with regional development funding supporting the development of modular technology.

At the same time, tendencies towards path dependence remains apparent within policy with the privileging of large-scale technologies, despite the likely need to align with UK Government strategy due to powers not possessed by the devolved WG. The WG as an institution has limited capacity to support the MEI, when coupled with a drive to reach economic and energy targets quickly it seems likely that the easiest options will be pursued, particularly if the opportunity is presented by the industry.

One of the key recommendations of the report was for WG to support the evolution of Marine Energy Pembrokeshire (MEP) to become a pan-Wales organisation called Marine Energy Wales (MEW). In turn, the WG was supportive of:

> "the industry's commitment to push forward with Marine Energy Wales as a focal point for promoting Wales, its resources and this growing industry" (Griffiths, 2016).

This suggests the mutual support relationship required by actors in order to progress aspects of the industry. The industry requires the WG's legitimation of their activities and the WG require the industry to drive initiatives forward. The change to MEW was viewed positively amongst interviewees as the organisation could provide a collective voice across the industry and showcase what Wales has to offer. The empirical evidence shows that there are common issues being experienced by developers and these organisations considered that the WG would only "respect" (TD4) a collective voice that could be provided by MEW. This shows the positioning of MEW as an intermediary that seeks to represent the industry and moderate knowledge flow between innovation and governmental actors, effectively creating a network between niche and landscape actors.

The lack of influence exerted by the WG is prevalent throughout the Task and Finish Group report. The report is cited as part of WG's 'strong commitment' to work closely with the MEI, yet it also highlights that EU policy provided the stable platform for technology development. Concerns are raised over the lack of leadership from the WG on "decisions [that] are taken in Westminster or in Brussels" (Task and Finish Group, 2016, p.4). Previous policy, particularly the 'Energy Wales Low Carbon Transition Action Plan', was considered not to be as clear in setting strategic direction for ME as for other industries. Whilst this prompted formation of the Task and Finish Group, the outcomes of the report provide limited insight into how these changes will be achieved. The desired outcomes are particularly curtailed by devolution and the limited powers possessed by WG.

It could, perhaps, be suggested that the purpose of this type of group is to generate industry networks and social capital between industry and institutions. This is a development that the WG can intermediate even with its limited statutory power to enact recommended changes. However, interviewees highlighted how governmental ministers engaged with the industry changed every political cycle and there was a danger of the Task and Finish Group recommendations being "left on the shelf" (SC6). Industry involvement, particularly that of MEW was viewed as insurance against this. It could therefore be argued that the measures the WG utilise ought to be apolitical and part of a longer programme of intervention. The success of this type of initiative could be called in to question where the two technology developers on the Task and Finish Group are no longer operational. The loss of social capital through this turnover is important and presents a significant loss of investment on the part of the WG in fostering relationships with the industry.

The Task and Finish group calls for:

> "Welsh Ministers and Assembly Members with an informed appreciation and understanding of the potential ME can play in Wales and who will provide strong, clear messages and champion the industry, which will instil investor confidence and provide a clear 'Wales is open for business' message" (p.5).

This crystalises the growing evidence that there are issues with the market creation mechanisms in Wales, where short-termism means that resources are ill-used within an industry and by the government. The less-developed status of the region and pre-commercialisation stage of the technology development means that these resources cannot afford to be lost. It is as though in the market creation process, the lack of salience to the strategy in Wales is stalling industry development. This makes it timely to analyse the market creation outcomes evidenced in Wales to understand how the measures listed in this chapter contribute or detract from industry transition.

5.7 Discussion of market creation mechanisms

This chapter has explored some of the institutions, policies and regulatory powers that are at play in the MEIW. Four institutions interact to govern the MEIW that are seemingly motivated by different outcomes; UK Government focuses on energy security and the environment, WG and CE focus on the economic whilst including environmental goals, and NRW has an environmental focus. There is an apparent hierarchy amongst these institutions with the UK Government controlling electricity pricing and CE has exclusive rights over seabed consenting, with other aspects of consenting undertaken by NRW. This shows the powers that are not devolved yet have significant influence on market creation for transition. This said, the WG can institute its own policies to mobilise market creation, in the fields of economic development, the environment, energy, health, and local government.

Despite the presence of these actors, the evidence suggests that there is an institutional misalignment in Wales. Where WG could enact a regional framework within that created by the UK Government, questions arise as to how or whether the MEI can be progressed in such a situation. Does the complexity of the marine environment demand a collaborative approach in order to draw away some of the onus that is placed on developers? Welsh Government policy (2012a) outlines that whilst technical design and performance are within the control of the developer, site-related risks such as grid connection, environmental data and monitoring are complex for developers to manage and better results would be achieved through government intervention. A collaborative approach is seemingly enacted by CE and NRW in the siting sphere, but of little evidence between UK Government and WG. The supposition that the government would seek to support a new technology trajectory and render a region attractive to innovators is subject to many clauses. The nature of relationships and how transition is influenced will be considered more fully Chapter 7. In the interim, the principal market creation activities are summarised in Table 5.5, where perceived market creation failures are highlighted in bold.

Year	Month	Outcome
2013	Feb	TD6 consented
	Feb	TD6 receives funding from UK Government
	June	House of Common' Energy and Climate Change Committee say Severn Barrage proposal unproven following Severn Tidal Power Feasibility Study 2008 - 2010
2015	Nov	ORJIP website goes lives
2016	N/A	Task and Finish Group Report
2017	Jan	Royal Assent 'The Wales Act 2017'
	Mar	Swansea Bay City deal signed by Prime Minister Theresa May
	Sept	Money to further Morlais activities from EU and WG
2018	Jan	WG announce their support for the Swansea Bay Tidal Lagoon awaiting UK Government response
	May	**BEIS inquiry into the UK Government's activities around Swansea Bay Tidal Lagoon**
	June	**UK Government withdraws support for Swansea Bay Tidal Lagoon**
2019	April	Energy consenting powers further devolved to WG
	May	**All party Letter of 91 MPs demanding support for UK ME development**
	July	Wales-Ireland cooperation formalised

Table 5.5. Key market creation events Wales.

Source: Author's Own.

The timeline shows the tension between UK Government and WG goals and objectives, and the complexity of multi-level governance. The 'failures' in market creation relate to large-scale projects that were supported by the WG but were within the consenting and fiscal capacity of the UK Government, with a seeming conflict between endogenous and exogenous drivers for change. The Severn Barrage and Swansea Bay Tidal Lagoon are two technologies that have dominated discussions of the MEIW for some decades but require the support of the UK Government to fund the development and encourage transition within Wales. This evidence highlights the misalignment between the different territorial governments and the limited influence of WG actors on this selection.

Following the further devolution of consenting power for RE in 2019, nuclear remains within UK Government consenting. In January 2019, the proposed Wylfa Newydd project in Anglesey was put on hold when the UK Government failed to come to an agreement with Hitachi. This caused ripples within the Welsh political sphere, with a minister highlighting that:

> "Wylfa Newydd is the biggest economic development project in Wales for decades, capable of delivering significant long-term economic benefits. The critical mass of home-grown Welsh and UK capability within the Horizon Nuclear Power organisation is vital to see this project through" (Skates, 2019).

This path dependence on nuclear and more generally large-scale RETs could explain the use of WG funds for projects outside of WG control. As a less-developed region, there is an imperative to pursue high employment technologies, but at the same time it is not wholly within devolved government capacities to bring them to fruition. The WG chooses to put its support most heavily behind technologies that can be viewed as most likely to 'win', probably driven by this need for economic growth. However, in the context of market creation for RETs, UK Government's goals are a more significant determinant of the winners. In short, in the context of the MEIW, the UK Government has the most influence.

It cannot, thus, be assumed that the Wales Act 2017 resolves all governance issues. Prosperity for all: A Low Carbon Wales (2019) highlights:

> “UK Government retains responsibility for most economic and fiscal policy, large-scale power generation, electricity transmission, heating, vehicle standards and licensing, and heavy industry” (p.50)

This includes Wylfa Newydd but essentially does enable Welsh consenting of the Swansea and North Wales tidal lagoons – as these fall below the new 350MW threshold - but not the proposed Cardiff or Newport lagoons. This duality between low-carbon and renewable, centralised large-scale and de-centralised modular generation becomes more apparent with the WG’s focus on nuclear and tidal lagoons.

The evidence in this chapter begins to show how economic growth goals influence market creation activities in Wales. There is the possibility that this narrative tends to marginalise developers of technologies that do not create a high number of jobs. This introduces some of the co-ordination issues where, even within areas of its control, WG has found it difficult to achieve a balance between economic imperatives and environmental regulation. This aspect was hypothesised to be complex within any region but seems to be exacerbated in a less-developed region. Lack of internal cohesion and guiding visions are shown to impact the ability to communicate objectives (Rotmans and Kemp, 2001; Berkhout et al., 2004; Inkpen and Tsang, 2005; Tsai and Ghoshal, 1998) and potentially impacts WG’s ability to project a clear agenda to other institutions such as the UK Government. There is perhaps a need for endogenous cohesion of aims so that the appropriate exogenous support may be sought out. This is underpinned by the interview data narrative where many interviewees were critical that WG did not exhibit the same political support for the MEI as the Scottish Government.

The apparent lack of direct intervention by the WG contrasts with the UK Government. The Marine Action Plan 2010 recommends strategic co-ordination between statutory agencies and stakeholders to produce roadmaps. These road maps set out the actions of both the private and public sectors to fulfil the vision set out. The road maps arguably provide momentum to the energy industry development as they co-ordinate stakeholders, assess the state of the industry, promote knowledge sharing, and provide targets for the industry to work towards. These roadmaps had been created in Scotland in 2004, highlighting the proactive stance of the Scottish Government in supporting the ME transition.

This said, the evidence suggests that WG is active in considering the opinions of industry, supporting the development of knowledge flow and undertaking many policy consultations and convening the Task and Finish Group. However, interviewees were concerned how onerous it was to respond to policy consultations. Interviewees stated that ultimately the visible actions of the WG were the crucial thing and that “public affairs are more beneficial than policy" (TD4). This highlights that there are multiple ways to create market pressure and open dialogue can be a productive method - aligning with the concepts of knowledge sharing to support path creation. This knowledge sharing is supported by social capital and WG were praised for being open to “all kinds” (SC5) of organisations joining their trade shows, meaning that it was possible to make many leading developers aware of the opportunities in Wales. It was said that “many [developers] weren't aware, particularly as there hasn't been the marketing behind it like in Scotland and Cornwall where a lot of resource has been put in” (SC5). It could, therefore, be concluded that whilst WG has limited institutional capacity, there is a recognition of the importance of alternative methods to encouraging technology development.

This introduces the idea that WG does not have the full range of power to sufficiently express agency; whilst working within the framework created by the UK Government there is still the possibility to enact policy and activities that promote market creation. However, it is striking that Welsh Policy often infers that support will be given to the MEI but there are no direct statements of how this will be achieved, despite the calls of the Task and Finish Group. This could be interpreted as an absence of direct support for the industry, with gaps in knowledge as to ‘how’ things may be achieved rendering the region less attractive to prospective developers. Further, the policies become less clear about the governance tools that will be employed to encourage the industry despite early policies being quite prescriptive. This perhaps relates to the fact that whilst WG has some powers of self-determination, the lack of financial self-reliance is prohibitive.

Overall, the governance of the MEI within Wales at best can be described as messy. The evidence makes apparent that many of the difficulties encountered by the industry in Wales is not due to institutional thinness as hypothesised in the context of research question 1 as there are evidently many institutions related to the MEIW. Instead, there are many institutional deficiencies within the market creation mechanisms that are exacerbated by limited capacity of a less-developed region. As such, it cannot be concluded that a niche has been created through market creation mechanisms for ME. Where measures seek to foster a market for RETs, ME is not offered a protected proto market within which the industry can experiment (Geels, 2002). In this scenario, for some of the key strands of funding, ME technology must compete with other, more developed, technologies. This is relevant when addressing a pre-commercialisation technology which could be assessed to be in the early-to-mid stage of technology experimentation, where efforts to pre-domesticate the technology and provide some market certainties are essential. Part of the assessment of whether this technology might be a success or a failure depends on whether there is a likely market at the end of its experimentation phase.

Regional innovation policymakers are often credited with greater success in developing local policies (Hansen and Coenen, 2015; Asheim et al. 2011; Cooke 2007; Fløysand et al., 2015; Isaksen and Remøe, 2001; Jakobsen and Høvig, 2014; Njøs and Jakobsen, 2018). However, in Wales successful policy for innovation is overshadowed by a growth narrative and a risk adverse attitude where overt support for the technology is required as part of the pathway to success. In seeking to create policy that supports employment and growth, the mechanisms utilised could be considered insufficient to support the MEIW. These factors contribute to a need for a supportive industry environment with actors that are engaged in promoting technology development. These innovation support mechanisms will be explored in the next chapter.

Chapter 6 Innovation Support

6.1 Introduction

This chapter considers the evidence generated from the interviews and policy document analysis to understand the activities within Wales that support innovation. Related to the system innovation literature, these activities constitute technology push mechanisms where an innovative technology 'breaks' into the marketplace.

The preceding chapter highlighted how various actors engage with the creation of a marketplace, these mechanisms include the price of electricity, policy, and consenting processes that encourage certainty around technology demand. As a result of the devolved institutional arrangement in Wales, the multiple levels of governance create a complex institutional environment for the technology actors to navigate.

The evidence within this chapter also highlights the actions undertaken by the industry to engage with this complexity. Initially, the financial framework within which actors operate will be considered including policy, grants, and private funding. Next, an analysis of how actors within the industry focus on innovation includes Welsh Universities, Marine Energy Pembrokeshire (MEP), Marine Energy Wales (MEW), developers, and the supply chain. How knowledge sharing is promoted with the aims of supporting innovation will then be considered in relation to the theorising advanced in the literature review (chapter 2). Finally, there will be an evaluation of how these measures support innovation.

6.2 Financing innovation

6.2.1 Overview

Two clear concerns emerge for renewable energy technologies (RETs): the cost of energy to the customer, and the need for investment from the public and private sector in order to achieve sufficient reduction in this cost. Nowhere is this more apparent than in marine energy (ME) policy. In the context of devolution, it is possible for the Welsh Government (WG) to utilise policy to influence technology design. Where the control of the price of electricity per megawatt-hour was outlined as a market mechanism, financial support of the innovation process also contributes to technology transition. Whilst these aspects have been separated in order to understand their contribution to transition mechanisms, they are inextricably linked. As an example, the prospect of a stable market can help raise funds for innovation. In Wales, as highlighted by the case study contextualisation, grant funding comes from EU convergence funding aimed at supporting regional development and this section will consider the impact of grants on developer's activities. Further, how public finance availability influences access to private financing will also be considered here.

6.2.2 Policy interventions

The key theme that emerged from the market creation chapter was the cost of electricity to the customer, this goal also informs innovation steering where technologies that are further from the market are disadvantaged. The persistent comparison of ME with other RETs drives policy demands of "continued focus on targeted innovation…to bring costs down sufficiently, within a stable support environment" (Welsh Government, 2011). This perception of 'costly' ME is further exacerbated by the conception of 'necessary' future technologies being stretched to embrace nuclear. When accounting for whole of life cycle and different technology types, it is likely that nuclear will be a less cost-effective low carbon energy source than estimated (Barron and Hill, 2019). However, the policy framework reinforces support for incumbent technologies or those RETs that are at a higher technology readiness level. This raises questions, not within the scope of this study, as to the differential lobbying powers or access to governmental actors between incumbent and niche technology actors.

The disconnect between policy goals and technology is apparent in the UK Government's policy (2015) which calls for three pilot tidal arrays in UK waters by 2018. These timelines were considered inappropriately tight by interviewees, including a statutory interviewee. This highlights a challenge in encouraging innovation whilst providing timeframe expectations; technology-specific goals to generate a sense of stability can become problematic when not achieved. Whilst significant progress has been made within the industry, missing these goals may be viewed as an issue with the technology rather than with the timeline established. This timeline was said by interviewees to have been also driven by over-promise on the part of the ME developers in the hope of securing funding.

Support for innovation funding for the MEI becomes apparent in both UK and Welsh policy from 2012. Welsh policy calls for grants towards capital cost and revenue subsidy (Welsh Government, 2012b) with economies of scale and innovation possible through supply chain optimisation and appropriate financing (UK Government, 2012). The UK Government (2012b) policy is candid with figures for marine development, stating that cost of energy will need to reduce 50-75% by 2025 to around £100 per megawatt-hour - an ambitious pathway necessary to compete with offshore wind. However, in 2018 the cost of offshore wind is estimated at around £46 per megawatt-hour by 2025, meaning that offshore wind remains a significantly more cost competitive than wave (£296) or tidal (£253) (Department for Business, Energy and Industrial Strategy, 2018).

Significantly, a WG study (2012b) acknowledged that:

“if investment in marine renewable energy projects wasn’t risky, then industry would have grown already, and there would be no need for any intervention to achieve the potential deployment capacity” (p.39).

Developers cannot be as ‘fleet of foot’ as supply chain organisations meaning that investment uncertainty is magnified for the innovators (SC4). These entrepreneurs are argued to drive the innovation system within TIS literature (Carlsson and Stanckiewicz, 1991), meaning that supporting the development of technology is important. Grant funding was viewed as an important mechanism for projects to ‘forge ahead’ due to the security of capital supply.

The link between the provision of public funding and securing private funding is apparent. UK Government policy (2014c) states that the industry is leveraging £6 of private investment for every £1 from the public purse. The WG study (2012b) asserted that WG or EU funded projects are a sign to private investors of confidence in the industry. Yet there is a risk with governments investing in projects; the two disbanded technology developers in Wales show the possibility of public money funding technology development, as arguably the return on investment was lost. Indeed, the literature highlights the ever-present possibility of governments over-reaching with inappropriate initial selection (Hepburn, 2010; Aghion et al., 2019). The riskiness attached to supporting technology development becomes more apparent, and the next sections will address the problems created by arrangements for support in Wales.

6.2.3 Grant funding

The reform of the structural funds allowed the tailoring of interventions utilising EU funds (Bailey and De Propris, 2019), where a sum of around £100million has been invested in the MEIW. Whilst this figure was considered to be significant by the industry, there are intricacies experienced by developers in utilising the grant funding. Interview commentary converged around key themes: the benefit of the funds, the restrictiveness of some of the regulation, and – invoking social capital issues - the continuity of relationships with supply chain organisations. All developers highlighted the integral role grant funding played in progressing innovation, suggesting that it is a useful innovation support mechanism.

Developers noted that the need for match funding had two outcomes: as a sign of financial capacity of the company, but also as a potential hurdle for those unable to raise funds in the early stages of development. One developer highlighted how €60million had been spent on the project over a decade before securing public funding; for this company, the availability of funding made the specific region attractive, contributing to technology embedding.

There were further fund management issues identified by the developers, with the required WEFO business plan taking around a year to fully create. The way in which the funding is administered is also said to create problems as payment is retrospective and there is the risk that some elements that are claimed will be turned down. An interviewee was perplexed by the system of WEFO paying the claimed amount before then auditing and reclaiming rejected expenses. The interviewee estimated that advance payment would present the same risk to WEFO but would provide more security for the developer.

> "There would be so many more people wanting funding if it wasn't retrospective, and I don't think it would impact on their governance in the slightest. Cashflow is king, as in any small business, it's slightly unsettling" (TD5).

A cross-cutting theme, the management of EU money raises questions as to what extent these complexities are specific to the MEI or experienced more widely (Bachtler et al., 2016). It could be surmised that the demands of EU grant holders would be similar. However, it could be suggested that the nature of these ME developers, as groups of engineers typically with no previous experience engaging with public funding mechanisms, would introduce a significant period of learning. As mentioned, the civil servants that support the application process have limited knowledge of the pre-commercialisation technology. TD1 clearly stated that the ability to apply for and manage these funds was supported by a team member having previous experience within a university. TD3 had a staff member who had worked in public funding, highlighting the benefit of these skills for daily operations.

The five developers interviewed highlighted that it was necessary to have an individual tasked with the management of the funds. One interviewee estimated spending one to two days a week looking after claims or applications. In particular, the necessity to gather three quotes during the tender process was thought to be "daunting to people who have no experience with grants and could really trip them up" (TD1).

The tender process also introduced the possibility of lost social capital, where the current supply chain company may not be successful in the next application round.

> "It's a bit strange, really, because as a marine developer you would want to start

> your life with a supply chain company and as you go through various test stages and design iterations you would stay with them" (SC1).

It could be suggested that these practices could place an onus of transaction costs on developers due to a need to foster and maintain multiple relationships. This in turn increases the amount of resource that is devoted to the social aspects of technology development. At the same time, however, it is evident that through generating relationships with multiple supply chain companies the developer would access a greater range of knowledge. Developers also stated that in some instances they had found services at a lower cost or become aware of new supply chain companies. The EU funding allocated pre-Brexit was also cited as a "good outlet for someone to blame if you're asking for very particular things from a supplier" (TD3).

EU funding was thought to provide confidence to the private investment sector. It was felt that:

> "having the backing of someone like that, it's almost as good as a big investor. It works two ways; our investors had the confidence to put money in when WG had done due diligence. It's a bit like you've got a lead investor inviting others to follow" (TD1).

TD1 also outlined that it would also be necessary to give away more of the company's equity to secure private investment without grant funding. The match funding was considered to encourage public confidence as it demonstrates that developers have the financial capacity to support the development of the technology. In this way, aspects of innovation support interact with demand for transition, with governmental legitimation through the provision of grant funding the validity of ME as a technology type that contributes to sustainability is also supported.

The evidence suggests that there is a delicate balance in managing private and public funding, particularly due to the requirement of match funding. One of the disbanded technology developers was discouraged from applying for Stage 3 funding whilst completing Stage 2 funding. However, due to the funds being administered in rounds it meant that there was a two-year financial gap that the company had to self-fund. When this was coupled with some high-cost technological issues the reserve funds were diminished. At this point they were successful in securing a grant from another source but no longer had sufficient funds for the match funding. The timetabling of grants in rounds was estimated by the developer to be one of the contributory factors in the eventual disbanding of the company. This picks up on the temporal aspects of co-ordinating the different mechanisms needed to progress an innovation highlighted in the previous chapter. These mechanisms exist alongside the co-ordination that is required for transition.

A developer did state the fortune of match funding for grants coming from within the company, estimating that the bureaucratic processes of another funding body or private investor would become administratively overwhelming. Another developer highlighted that they use private finances to create some leeway in the procurement processes specified by grants to approach companies directly. It could be suggested that within this transition mechanism, the need for autonomy on the part of developers to pursue their desired technology trajectory is linked to private equity capacity. The evidence suggests that there is an optimal balance of sufficient public money to inspire confidence in private investment coupled with independent finances to support innovation.

It was also highlighted that following the European Union Referendum in 2016 that there was limited discussion of continuing support following Britain's exit from the EU (Brexit). The evidence suggests that this has impacted how the industry is viewed in Wales, leading some supply chain companies to view the MEI as a diversification strategy rather than a long-term source of business. Supply chain companies were sceptical that developers would remain in the region once funds were no longer available. This outlines further regional characteristics and the role of the political environment, where additional measures to encourage the embedding of a technology in a region may be necessary to provide balance. The impact of grant funding is explored further in the Q Methodology, however, there remain questions as to how private funding might influence technological innovation.

6.2.4 Private funding

The emerging observation for this innovation support mechanism is the need to manage the timetabling and utilisation of public and private funds. Public grants require match funding, where the evidence highlights that developers must preserve this capacity. Interviewees outlined that certainty of investment was integral to securing private finance. Early stages of technology development were considered the most difficult.

> "Once you have something people can stand on and drink a cup of tea on it, with desalinated water boiled by a kettle on board - you're suddenly getting money through the door and it gets a lot easier" (TD5).

In some instances, grant funding was used as a signal, but there were undisclosed funding instances of "good mates and crowd funding" (SC2) for individual technology types.

However, within Wales there is also a presence of indirect private financing coming from the supply chain, where nine of twelve supply chain companies interviewed outlined that they undertook work pro bono or at a very low cost. The future likely profitability of the sector was the main motivation for this innovation support. SC7 which is a firm with a large independent financial capacity valued the bottom-up learning that comes from working with the MEI in the early stages of development. It could be suggested that knowledge flow through the MEI benefits not only the developers but also the supply chain that will operate in Wales and elsewhere.

An actor providing unilateral support to technologies is the Milford Haven Port Authority whose position as a trust port, with a longer-term duty to protect the interests of the shareholders, enables a longer-term view to profitability. Similar to the CE, with the Milford Haven Port Authority "any profits that are made go back into the viability of the waterway economy for future generations". This has seen the port undertake significant investment in RETs more generally with £7.5m invested in solar photovoltaic at the time of interview in 2016.

Diversification into RETs is a long-term strategy to even-out the volatility of supporting the oil and gas industry. The port has its main source of income from piloting tankers; however, it is only once the tanker is in tow that income becomes secure. So, in a scenario where several tankers are waiting off the coast and the price of oil becomes higher elsewhere, they weigh anchor, and the port loses money. At the same time, the port views the income from the tankers as creating the ability to support the MEI. As custodians of the water with regional statutory power, the Milford Haven Port Authority identifies opportunities in the MEI to promote the long-term economy.

The support offered by Milford Haven Port Authority has come in several guises including allowing the use of the 'pickling pond' which is a saline water pond. Significantly, a technology company used the facilities "at almost zero cost”. The Milford Haven Port Authority stated that whilst no money was made from the setup, the port secured a “long term commitment from them to use Pembroke Port and manufacturing facilities – that’s the dream." Since the interview, this technology company has disbanded. However, even in the short-term the strategy had worked as other developers have signed memorandums of understanding with the port. This collaborative ethos in a region has the potential to support innovation and ultimately contribute to transition through accelerating the development of productive relationships between future cluster members. In turn, innovation is better supported and ME transition in particular will be accelerated due to faster technology design processes.

It can be concluded that for innovation support through financial mechanisms to be successful, multiple sources of finance are required to support the many facets of creating innovation. Whilst this section outlines the financial mechanisms utilised and the recurring requirement of actors able to take a longer-term view, it also introduces the choices actors make and the need for multiple approaches to support innovation.

6.3 Welsh Government support for knowledge

Knowledge sharing focus in early policies sought to stimulate ‘green thinking’ amongst industry and the public. With the purpose of accelerating industry, knowledge sharing goals became explicit in UK Government policy in 2010 and appeared in WG policy in 2011. The UK Government ‘Marine Energy Action Plan’ 2010 advocated that capital be provided for research to support demonstration and deployment.

The WG’s policy (2011) is the most extensive policy engagement that has been undertaken with the industry to date, spanning 2007 to 2011 and undertaken in multiple stages. Stage 1 in 2007 consisted of initial literature review, stakeholder engagement, data gathering, and GIS mapping. Then in 2009 and 2010 the data gaps identified in Stage 1 were explored in discrete reports as part of Stage 2. Then finally Stage 3 developed the framework coupled with a Steering Group with invited members from a wide range of actors including the CE, WG and Countryside Council for Wales. The project stored its open access data in a way that would allow layering of additional information.

Alongside informing policy, the 2011 policy was also intended to support developers, yet these actors were not included in the consultation. There is further evidence of these behaviours within Wales where the development of the Technical Advice Note 8 which issued guidance on land use planning in relation to RE did not consult key actors (in that case, wind energy companies and local planning authorities) in the most crucial dimensions of policy formulation (Cowell, 2010). This resulted in significant criticism of the Technical Advice Note and a disconnect in what was currently taking place in Wales (Cowell, 2010).

It could be argued that understanding the requirements of developers would have given the data more utility. Further, had discussion with developers such as Minesto taken place, whose technology can recover energy from low density flows, a more precise baseline would have been developed. To map a resource makes assumptions about the technologies that can exploit it effectively (ORE Catapult, 2018). Most significantly, the 2011 policy document came against constraints with communicating data, particularly GIS, and this was down to data ownership, licensing and availability.

The WG then commissioned the Marine Energy Infrastructure Study (2012a). Undertaken by Halcrow Group Ltd, the 2012a policy made use of the stakeholder consultation and strategic data generated by the 2011 policy. The study also added supply chain specialists, BVG Associates, and other stakeholders to identify industry needs. This consultation did include developers to understand the modelled resources and recommended a Strategic Environmental Assessment of the development of primary resource areas in Welsh waters.

What was unique about this consultation is that the final information was communicated in two different styles of report. Stage A was the complete study including background information and was promoted as more suitable for the public or those that had an extended interest in the industry. Stage B was targeted specifically at readers from within WG that:

> "are seeking explanation of the need for government intervention in supporting growth in the marine renewable energy industry" (Welsh Government, 2012b).

As the previous chapter showed, understanding of the complexity of supporting a ME transition is perhaps lacking in Wales. The type of information that is available is important, as is the consideration as to how policymakers or civil servants might access it.

The 2012a policy identifies the opportunity for knowledge export but also the significant gaps in knowledge about the impacts of multi-device arrays. Indeed, the environmental data that is required with each device does not consider how multiple technologies may interact with one another and the environment. This was viewed as a constraint to the consenting of large arrays. It can, however, be argued that the ambiguities of the technologies themselves makes it difficult to anticipate how the devices will act in arrays. This said, the study goes some way to forecast stability in the industry and advocates for the wider diffusion of the 2011 data. There was the further recommendation to consult with developers to understand how devices would be manufactured so that the supply chain and port facilities could become integrated.

The principal recommendations from the 2011 and 2012a policies highlighted gaps in knowledge around consenting, licences, and the need to make environmental data publicly available. Interviewees echoed these recommendations highlighting that readily available data for a region would accelerate technology development. In support of this, the 2012a policy suggests that the WG and regulatory authorities may be pressured to consenting development without enough information. Recognising these bodies are legally responsible for protecting the marine environment, there was a concern that mistakes "could lead to control of consenting being withdrawn and re-centralised" (Welsh Government, 2012a, p.38).

Many of the UK Government and WG policies are based upon scoping reports conducted by consultancies, who typically liaise with other organisations and hold a consultation period. This is positive as it can negate a lack of capacity on the part of the governments and can provide a more rounded view of the industry. It also provides the opportunity for firms to share their lessons learnt in a 'safe' manner due to data protection and anonymity rules. Participants can also speak freely regarding issues related to the governance of the industry or wider issues, again due to the same data handling guidelines. This links to many of the issues addressed in Chapter 2 such as the importance of social capital and trust. However, in thinking of the status of the knowledge that is produced, there is the potential for the absence of local or pertinent knowledge. The activities of research actors that are external to Wales generates unanswered questions as to the research capacity within Welsh Universities to support technology development.

6.4 Universities supporting innovation

6.4.1 Introduction

Universities are actors that support innovation through the communication of research findings and the provision of trained personnel (Etzkowitz, 2003). There are three principal research projects that have contributed to the MEIW - the Low Carbon Research Institute (LCRI) and SEACAMS 1 and 2. The activities of these projects will be outlined and followed with a discussion of how innovation is supported.

6.4.2 The Low Carbon Research Institute (LCRI)

The Low Carbon Research Institute (LCRI) operated between 2008 – 2015 and was a collaboration between Welsh Universities. Originally funded by Higher Education Funding Council for Wales (£5.2million) and later ERDF (£19.2million), the work of this institute advanced technologies and low carbon research. Due to the LCRI closing before the fieldwork period and the subsequent movement of members to other projects and initiatives, the LCRI Summary report (2015) was utilised to understand activities and is referenced throughout this section. Where other outputs of the institute include academic journal papers, these relate mainly to technical aspects of innovation including device interaction with the environment.

With an agenda to reduce energy demand, generate knowledge and skills transfer, disseminate research, and encourage industry partnerships (Low Carbon Research Institute, 2015), the LCRI also worked across a range of sectors. Swansea University managed the LCRI Marine programme to provide independent research to build a sustainable marine energy sector in Wales. The funding of this programme was considered a catalyst to securing other funding, attracting a further £20.4 million from UK research councils, £20.2 million from EU frameworks and £15.1 million from industry and partner universities. The funding that was leveraged by the LCRI was estimated to be “an example of how government funding can be used to build research capacity and create jobs in

Wales" (Low Carbon Research Institute, 2015, no page number). This echoes the experience of developers who leverage grant funding as a signal to private investors.

The work of LCRI Marine identified that developers have a common problem:

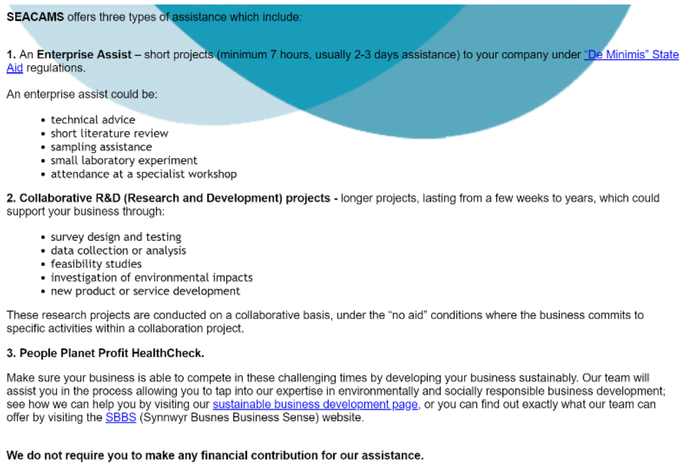
> "which is the removal of technical and environmental uncertainties in order to convince government to provide appropriate market incentives and persuade utility investors to build the first commercial projects" (no page number).

In order to address this issue, research explored aspects that ranged from technical device detail to environmental concerns. An important outcome of the programme was the installation and monitoring of a directional Waverider buoy that can produce detailed telemetry on the height and spectra of the wave. The device was claimed to help demonstrate the commercial viability of wave energy in Wales, with the aim of encouraging investment in Welsh projects.

6.4.3 Sustainable Expansion of the Applied Coastal and Marine Sectors (SEACAMS)

SEACAMS1 (Sustainable Expansion of the Applied Coastal and Marine Sectors) was a five-year project from 2011 – 2016, followed by the three-year SEACAMS2 project running until July 2019. The SEACAMS projects focus on marine technology within its locale, offering services that relate to environmental monitoring, sediment, sustainable resource development, and coastal zone management alongside engineering expertise.

SEACAMS1 pooled the specialisms of Bangor, Swansea, and Aberystwyth Universities, offering sea vessels, laboratories and field equipment. The project aimed to improve access to Higher Education facilities and knowledge to enable research that can be utilised by industry. SEACAMS1 had many different levels of assistance to offer businesses and are included in Figure 6.1. As a recipient of EU funding, SEACAMS 1 assisted businesses in convergence regions. However, businesses that were from outside the area that could demonstrate that their work would benefit the convergence region could qualify for support, up to a maximum of 20% of projects. SEACAMS 1 was unable to work with regulatory bodies, central government or local authorities. These factors suggest a strong bounding to the work that could be undertaken by SEACAMS 1.



SEACAMS offers three types of assistance which include:

1. An **Enterprise Assist** – short projects (minimum 7 hours, usually 2-3 days assistance) to your company under "De Minimis" State Aid regulations.

An enterprise assist could be:

- technical advice
- short literature review
- sampling assistance
- small laboratory experiment
- attendance at a specialist workshop

2. Collaborative R&D (Research and Development) projects - longer projects, lasting from a few weeks to years, which could support your business through:

- survey design and testing
- data collection or analysis
- feasibility studies
- investigation of environmental impacts
- new product or service development

These research projects are conducted on a collaborative basis, under the "no aid" conditions where the business commits to specific activities within a collaboration project.

3. People Planet Profit HealthCheck.

Make sure your business is able to compete in these challenging times by developing your business sustainably. Our team will assist you in the process allowing you to tap into our expertise in environmentally and socially responsible business development; see how we can help you by visiting our sustainable business development page, or you can find out exactly what our team can offer by visiting the SBBS (Synnwyr Busnes Business Sense) website.

We do not require you to make any financial contribution for our assistance.

Figure 6.1. Assistance offered to technology developers by SEACAMS1.

Source: SEACAMS1 Website

SEACAMS2 is a joint venture between Bangor and Swansea university, part-funded by the ERDF and continues to focus on convergence regions. The project has direct interaction with the MEI but does not support business plan development as was the case in SEACAMS1, with a "brief diagnostic" of between seven hours and two weeks of discussion to establish whether the project is possible (SC9). These initial discussions include a ring-fencing of IP where typically the IP was retained by SEACAMS and licenced out to the collaborator on "very favourable terms" (SC9).

SEACAMS 2 established a data depositary that is an open access resource to allow others to also deposit findings. This was viewed by the interviewee as a good source of 'free data' for companies that do not have a turnover. However, the data is protected for a period before being publicly available. Once publicly available, those that wish to access it:

> "will have to make a request for it, just so we can make sure where it's going. Hopefully this resource will live on past end of SEACAMS2 but this will cost money

to make possible" (SC9).

As of 2020, the project website contains many case study summaries detailing work that was undertaken. The iMarDIS data portal is also live, outlining the geographical areas for which data is available.

6.4.4 Discussion of Universities' contribution to innovation

Whilst engineering support is required for technology development, the activities of the universities could be considered to seek fulfilment of academic goals rather than the best interests of innovation support for the MEI. This is inferred from the gatekeeping of the data that is available in a bid to encourage engagement. Whilst the universities have developed their own networks, they have not contributed to wider networks within Wales, nor could it be said that there is a particularly lasting legacy of the knowledge generated. This leaves a significant gap in the support of innovation, as universities are frequently shown to be instrumental in the development of innovation in a region and subsequent patenting of inventive ideas. Whilst not specifying the exact details, an interviewee did highlight discontent in the industry that vessels had left Welsh Ports without speaking to the wider industry or the regulator. This was viewed as a political move as the level of help required by the industry to "get in the water" should make collaborative approaches a priority.

The academic community is frequently referenced in policies. This promotion of academia and its impact by the WG is valuable as it provides legitimacy that can ensure industry interacts and shares knowledge. It can also serve as 'advertising' to potential investors or developers, with the narrative of a knowledgeable industry and a Government that is "committed to innovation". Welsh Government policy (2012c) highlights the level of funding that was committed by the WG to the LCRI, "one of 'the best examples in Europe of research, innovation and sustainable development' according to the President of the European Commission, J M Barroso" (Welsh Government, 2012c, p.23). Further, funding of SEACAMS was viewed as fundamental to "positioning Wales at the forefront of key innovation, research and development on the low carbon technologies that will power our future" (Welsh Government, 2012c, p.23).

The evidence suggests that the primary focus of these projects relate to technological design and environmental monitoring. The work packages in SEACAMS 2 also contributed to social aspects. SEACAMS 2 data influenced the siting of the demonstration zones as the site proposed in Anglesey was subject to waves of sand sedimentation (SC9). This shows the contribution of Welsh Universities to supporting innovation in the MEIW with a focus on technological aspects, and also embedding processes such as regional environmental impacts of technology siting.

The limitation of SEACAMS activities was that data could only be gained through collaborative research, where many of the firms in the MEIW "simply want some data" (SC9). The data from SEACAMS 1 was accessed by request and could not be "shared around" in order to ensure that SEACAMS 2 was approached with research projects (SC9). This has significant implication on the flow of knowledge within the MEIW and the type of collaborative relationship that can be forged. Similar to the requirement of match-funding for grants, the capacity on the part of a developer to undertake collaborative research may preclude developers from engaging with the Universities. Further, the IP regime where SEACAMS licences out the intellectual property to the collaborator also configures the type of collaborative relationship that can be forged, a feature not unique to Wales (Cowell and Webb, 2019).

Attitudes towards patenting and protection of IP varied across developers. TD1 had a patent family, which was managed by a patent attorney and was effective worldwide. Whilst the patenting process was expensive, TD1 viewed the process as important due to the many innovative components of the technology. One of the technical directors of this company had a lot of experience with patents and this was seen as essential in supporting the process, alongside WG and WEFO monies.

TD3 highlighted how they had many worldwide challenges to their patents, all of which had failed. The company concluded that this was proof of the innovative nature of the technology and evidence for private investors. TD5, however, had not engaged with patenting as it was felt that the expense and time-consuming nature of the process would detract from core activities. TD5's core activity was not to develop a "hugely innovative" device but to create a technology that utilised existing principles and needed minimal maintenance input. "Rather than create a Ferrari, we want to make a Land Rover" (TD5). TD5 also highlighted that in the patenting process it can often be down to finances; "IP is great, but not that great because usually the person with the bigger wallet wins - and we're not the ones with the big wallet."

The evidence suggests that the potential impact of SEACAMS' IP regime may be limited and highly dependent on the patenting outlook of the developer. However, the gatekeeping of access to data is likely to impact the industry. An interesting tension was raised in interview about access to grant funded research, where TD4 argued that research funded by the public purse should be open access. As the second or third technology to locate in the region, TD4 expected much of the base data to have been established. When asking the experience of others from outside the region, many companies stated that their findings with regards to environmental interaction was protected intellectual property. The interviewee went further to highlight how the company that they had requested the information from had disbanded and that knowledge was now lost.

When TD4 disbanded, extensive activity was undertaken to disseminate information about problems encountered through MEW and some employees were also operating on a consultancy basis. The interviewee also highlighted that pathfinding is a difficult and expensive process, and this should be factored into government grants. In particular, this company had undertaken an extensive amount of activity to gather data on environmental interaction with devices. They feel that this is one of the areas that introduced risk to their development process and contributed to failure.

SEACAMS had the ability to operate in this way. However, the evidence suggests that 'repeat business' was a higher priority. Indeed, the SEACAMS interviewee outlined that publishing peer-reviewed papers generated a greater degree of consultancy work than attending events in the MEI, with the conclusion that "publications are better than trade shows". It must therefore be questioned whether the goal of this interaction with the industry is with the aim of transition and innovation support, or the generation of repeat consultancy opportunities and academic goals. Indeed, when included in the Q Methodology, Welsh Universities were considered to have had a minimal impact on respondents' activities.

Further, the removal of business model support in SEACAMS 2 is an indicator of the type of developer that was sought as a collaborator. It would be those developers at a higher technology readiness level who would not require this type of business intervention. The collaboration requirements constrain the relationships that developers can foster and limit the technologies with which the universities can engage.

Alongside the SEACAMS project, Bangor University has the CAMS centre which undertakes consultancy work. This is an interesting relationship as effectively the same team services both functions. The SEACAMS projects were considered to have bolstered consultancy enquiries for the services of CAMS. A developer highlighted how they employed CAMS to do a project as information was required within a quicker timeframe than could be achieved through a SEACAMS project. This suggests a tension between the availability of data and the ability to fund the research process.

However, the industry also engages with research support, and an interviewee mooted that some actors argue that the universities have taken business away from private organisation who do this type of work. It was noted that the universities do however provide research elements that a consultancy could not "and the cost differential is quite significant" (TD4). A developer echoed this notion with thoughts around the public sector being one of the main sources of innovation as "in reality the industry will lose its innovative nature as it becomes more commercial" (TD3). This raises interesting questions as to the role of universities in the knowledge ecosystem and how they might exist in a region that has strong or weak knowledge generation capacities. Indeed, where knowledge networks that rely on relational proximity or clustering exists, there is extensive research on how universities might integrate themselves in these networks (Leydesdorff and Etzkowitz, 1998; Etzkowitz and Zhou, 2017).

It was argued that academia does not communicate project results or findings well, and that there needs to be a concerted effort to do this (TD3). It was considered likely that "many of the 'answers' and information that technology developers need are within academia, but probably sitting on a shelf somewhere" (TD3). Whilst potentially an idle musing of an interviewee, the evidence suggests that the long-term contributions to knowledge from the Universities are to be found in academic journals, rather than held in the MEIW.

The evidence could be considered an example of the 'innovation paradox' (Oughton et al, 2002) with academic research not well matched to regional needs due to weak intermediary institutions and limited absorptive capacity (Goddard et al, 2012). Indeed, within Wales there are calls to scrutinise the knowledge-generating capacity of Universities with "presumed economic dividends" (Morgan, 2017, p.577; Huggins and Kitagawa, 2012). A key problem of the Welsh innovation policy is the privileging of universities for knowledge generation in a context where there is weak or uncertain demand for this knowledge (Morgan, 2017). The evidence suggests that in some way this weak demand is influenced by the requirements of the universities for collaboration and the prioritisation of academic outputs.

This said, established relationships in SEACAMS1 passed to SEACAMS2 suggesting the universities established some social capital with developers. However, it remains that dissemination of this research has had limited impact on the support of the MEIW for innovation and transition. In this light, it must be questioned whether the universities generated the right type of knowledge, disseminated it efficiently, or to what extent regional research is a factor in industry transition. This type of regional research includes the blanket approach adopted by the WG through the 2011 and 2012a approaches, and the hyper-local research conducted by the universities. This research focuses on the siting of the energy devices, where to some extent the principal query for the technology to integrate with the marketplace is the cost of electricity. What then have been the activities of other industry actors around innovation support?

6.5 Industry Engagement with innovation support

6.5.1 Introduction

Alongside the activities of the universities in Wales, there are other key actors that support the innovation process. The importance of Marine Energy Pembrokeshire (MEP) and Marine Energy Wales (MEW) were alluded to in the Market Creation Chapter, where this section will consider the core activities undertaken by the actors to support innovation. Following this, supply chain and developer contribution to innovation will be considered.

6.5.2 Marine Energy Pembrokeshire (MEP)

Marine Energy Pembrokeshire (MEP) was established in 2009 by the Pembrokeshire Coastal Forum. Pembrokeshire Coastal Forum conducted a survey on behalf of the WG to identify potential sustainable economic activities in the region. The aim of MEP was to foster partnership working between developers, the supply chain, academia, and the public sector. The goal was to establish Pembrokeshire as a centre for excellence for ME generation, in response to a declining oil and gas industry that employed many locals. This regional narrative has had a large impact on the activities undertaken by this actor in both supporting innovation and seeking to moderate transition.

The MEP has many outlets of activity: a working group, network development, an active email circulation of over 1000 contacts, and an annual industry event. The working group began with around eight people at the table and included the LCRI and Countryside Council for Wales. Group members had a range of roles and responsibilities, and the working group was viewed as the best way of working together towards a common goal with minimised bureaucracy. The working group has since extended to a booked maximum of fifty people at the table; this is a number limited by MEP in order to maintain frank conversation. In practice, before the official rebranding of MEP to Marine Energy Wales (MEW), MEP was undertaking activities to promote and develop the MEIW as a whole, acting in the capacity of innovation and transition.

Whilst MEP's activities started with embedding principles in mind, the actor has contributed greatly to supporting innovation through the organisation's network development. The local outcomes of activities will be discussed with respect to technology embedding in the next chapter. Locally, due to an employee of MEP having previously worked for the Milford Haven Port Authority there is a high degree of social capital. Milford Haven Port Authority considers that the MEP does much to attract ME developers to the region and is a part funder of the organisation (SC1). The MEP acts as a "single point of access for information. If we (MEP) take someone to do a supply chain visit, it's a lot of our time. We'll meet a developer, take them around the port, tell them about the capabilities of the region, they wouldn't get that otherwise" (SC6). Further, the MEP team considered partnership working to be a crucial component in supporting the MEIW.

> "We spend a lot of time linking people together, not only in our membership but with statutory bodies and in the industry. We might have a project that comes to us that is quite unusual so we would sit down and have a think about it and put them in touch with people who might be able to help. So it isn't that we're a project delivery agency, we're more of an introduction dating agency."

Many of the interviewees highlight that their connection with another organisation came directly from a member of the MEP team setting up a meeting. It would seem, therefore, that MEP is acting in an intermediary capacity to connect actors and develop a network. Significantly, at the time of interview in 2016, there were seven or eight developers that had come directly to MEP to ask for assistance in engaging with the MEIW. Whilst some were “improve my technology” (SC6) requests which were routed to the LCRI, many needed support in finding a location to test and a supply chain to support operations.

The informal communication established through MEP was seen as vital to the technology developers (TD1, TD3, TD4). Interaction with the MEP was considered crucial for both project and technology development. However, this ‘dating agency’ approach is costly. When MEP evolved into MEW, due to the ever-increasing demands on time and resources it was necessary to start charging for membership where previously it was free.

The annual industry events are a source of extensive knowledge sharing, with presenters sharing their experiences and updating the industry on the progress of their technology. The important element is that the "MEP event is not just about marine energy, it is taking lessons from across the board - learning what oil and gas have found” (SC6). The introduction of a 'Lessons learnt' session in 2016 was particularly interesting. Interviewees were, however, keen to stress that this would be a difficult task for developers as they would not want to risk ongoing investment in their technology. Supply chain companies however could simply anonymise the data. This shows potential costs associated with membership of a knowledge network, where there remains an imperative to preserve the image of the organisation. This echoes literature that shows how failure is likely to be filtered out without a high degree of social capital (Murdoch, 1995).

A constant presence at these industry events is a consultancy that has worked extensively in Orkney and has now expanded operations to work within Wales. A representative of the consultancy highlighted the similarities between Orkney and Wales and that there is great benefit to knowledge sharing between these two regions. When MEP was in development, MEP visited Orkney to undertake learning around organisational design. This suggests that MEP was proactive in recognising the potential symbiosis between the regions and demonstrate an understanding that regional characteristics can be influential.

The relationship between these two organisations came about due to work undertaken previously in the oil and gas industry, where one individual then became involved with MEP and encouraged a connection between the two regions. MEP has capitalised on this relationship by inviting the consultancy to speak at annual events - promoting knowledge sharing and further social capital. The benefits are mutual, in providing a platform to this consultancy the MEP provides legitimacy and this has meant that the consultancy has been able to expand its operations into Wales. The consultancy receives no fee for speaking but views it as an opportunity to network and tell others of their activity. Due to these activities, the consultancy can be considered as central to the knowledge network within the MEIW.

With regards to engaging with the network created by MEP, TD5 pointed out that the cost of the meeting is high when factoring the time, travel, and wages of those involved. Therefore, TD5 attends every few rather than each one. The MEP also has an extensive email list which they use to disseminate information. Emails include news from developers and the supply chain, calls for tender, job vacancies within the industry, and important regulatory points that are discussed in the working group. This means that the entire supply chain has the potential to engage with this information without attending working groups.

The MEP has developed awareness of regional supply chain needs, the need for interactions between multiple industries and undertakes action to intermediate and share knowledge. The Orkney consultancy had undertaken research that explored how the fishing fleet on Orkney had diversified and engaged with the MEI. As a result, MEP offered free places to Pembrokeshire fishing fleet organisations so that they were able to learn about the industry. The consensus was that "fishermen underestimate how much their knowledge of the sea can be useful and applicable to marine technology" (SC6) and MEP hoped to demystify what the industry is about.

When interviewing the MEP representative, the Task and Finish Group discussed in Chapter 5 was an ongoing process. Engagement with the group was viewed as an extension of

MEP’s activities that fell within their organisational evolution. Bridging the links between industry and regulatory bodies was a core aim of the MEP and became increasingly important as a result of demand from the industry. The MEP interviewee emphasised the multi-faceted role undertaken by all staff members and the 'juggling act' of emerging demands. With this in mind, the MEP commissioned a number of reports on the state of the industry in Wales that provide background information for potential industry entrants. These reports established MEP as a key knowledge actor in the industry and paved the way for MEP’s evolution into Marine Energy Wales (MEW), and these activities will now be considered.

6.5.3 Marine Energy Wales (MEW)

The most significant change in organisational profile from MEP to MEW was the introduction of paid membership. A need for an ‘exit strategy’ for the consortium of funders was apparent with MEW increasingly becoming independent and securing a sustainable future (SC5). However, the membership fees are considered by many to be ‘notional’ and are based on the number of employees in an organisation. The charging system is progressive, with low costs for a small business, and able to account for business growth. Premium membership brings additional benefits such as the inclusion of the company logo on MEW marketing materials; company input and representation into industry coordinated consultation responses; and assistance with stakeholder engagement activities.

Feedback on the annual conference particularly valued the open dialogue created through panel sessions, with views that this was essential to industry development and showing that knowledge flow and trust is valued within the industry. In line with this, MEW is of the opinion that NRW and CE continue to attend these events not only to disseminate the changes that they are instituting as organisations, but to also gather evidence and information to inform policy. As such, encouraging open dialogue at these industry events then serves the purpose of highlighting exactly what is needed to support innovators and ultimately speed up the innovation-led transition process.

Further in this aim of enabling open dialogue, consultants are excluded from the working group. Whilst consultants have argued that they are part of the supply chain and an integral part in taking the sector forward, MEW think that their presence would curtail the openness of conversation that is currently a key feature of the working group. The ability to maintain this open dialogue is called into question by a developer who believes that as the industry progresses members will be less candid with their response.

> "MEW does promote the Welsh industry worldwide but it has to be realised that there will eventually only be 1 or 2 winners within Wales. Whilst everyone sits and shares what they are doing in their activities and so forth, it is impossible for everyone to be 100% transparent because they are private companies and they do need to make a profit." (TD3)

The participants in MEW are not only based in Wales. Some members are supply chain companies that seek to engage with the Welsh industry; others are Welsh supply chain companies seeking to diversify; and others are developers that wish to understand more of the MEIW with a view of locating in the region. It can be surmised that the information shared at working group meetings and events have a wide audience. However, whilst MEW are spatially neutral to those that engage with the network, the principal aim of this information sharing is to support development of the industry in Wales. These activities are with the aim of territorial embedding of these interested parties in Wales.

The MEW like MEP continues to have contact from individuals who misconceive the size of the organisation, thinking that there is the capacity to support technology design amongst other features. MEW continues to forward the information on to relevant partners to ensure that these opportunities are capitalised upon. The focus remains on knowledge sharing. Particularly, the MD of a disbanded technology developer is on the board and is instrumental in helping the wider industry understand some of the difficulties faced during technology development. Furthermore, MEW hosts placements from the Nippon Foundation in Japan who are considering a future direction in marine energy but lack the skills and expertise currently. This shows that knowledge sharing remains at the core of MEW's functions and this in turn supports innovation and industry development.

MEW maintains a strong connection with the supply chain, "one of our main roles is getting the right people together and representing industry, and we can do that at a high level now". This work supports SMEs, outlining how to engage with the industry to win tenders, rather than thinking "it's for the big companies to mop it up" (SC5). MEP and MEW are integral to the development of relationships between technology actors in the MEIW. It is therefore timely to consider the contribution of the developers and supply chain to the innovation focus of the MEIW.

6.5.4 Developers and the supply chain

Developers were all keen to highlight the "hugely supportive supply chain in Wales". When going to tender, TD5 had many interested supply chain companies who told the developer that they were

> "not looking to make money on this job, we just want to get involved with you as a company because we can tell it's long term. We know you're not making money, so we can't charge you much" (TD5).

The evidence shows how fabrication supply chain companies originally thought along the lines of the price and quality steel of oil and gas, but soon came to understand the MEI requirements. Developers commented on how the supply chain companies sought to understand the design and contribute to the process. This suggests that supply chain companies in Wales engage well with developers to support innovation and technological design.

The role of insurers could be overlooked when considering the supply chain, but due to the risk involved with the development of an innovative new technology it is possible for these actors to support the innovation's path to the market. Insurers support developers with design and siting choices. In particular, the insurance interviewee elaborated how "brokers and underwriters are trained to think about and identify risk so they can bring expertise" (SC2). In this way it is possible to advise clients of the potential risks of the technological design and the developer is then able to evaluate whether the feature is necessary or can be “designed out” (SC2). These risk areas can also be addressed in presentation to investors, and the insurance company interviewed frequently supported developers in writing business plans. As an example:

> “whether the device is attached-to or piled-into the sea floor has more of an impact – the physicality of the risk of preparation activities plus equipment can see a cost variation from £5k for the former to £40-80k for the latter.”

Following initial risk assessment, insurance companies will then ask a Marine Warranty Surveyor to look through the plan and advise. Marine Warranty Surveyors are not a specified discipline but are typically ex-marines or navy personnel who have sufficient engineering expertise and sea knowledge to consider the plan. The role of these surveyors is to provide independent oversight; they are not consultants to the project advising on operations but determine the interpretation of warranty clauses (SC2). There are only 8-10 of these surveyors within Europe and many work outside of the EU, showing the level of specialised knowledge and potential time delays in gaining their services.

Insurance could wrongly be considered a project management activity, but the empirical evidence suggests that it can significantly impact project design and cost. Underwriters currently consider marine energy technology to be at a prototyping stage, “8000 hours in the water with no major changes are needed in order to consider taking the technology to the bank” (SC2). This requirement is applicable to technologies in Wales and presents a significant challenge in the progression of the industry. Crucially, no Welsh ME technology had achieved these hours by 2019. This also highlights the operational work still required before the technologies can engage with the electricity pricing mechanisms for market creation.

Interview commentary suggests that the ability to engage with knowledge development aimed at innovation is influenced by the size of the firm. On the one hand, firms need to have sufficient capacity to support the lifespan of the project. On the other, firms might view the demands of understanding the needs of a nascent industry too laborious for diversification that may not be long-term. The disbanded technology developer highlighted that the developers in the industry in 2017 have "got lots of ideas but there is a lot of learning they need, and most of that is in the supply chain. It’s all there."

The extent to which actors changed roles is a notable feature of the MEIW, there are many examples of individuals who have moved amongst many of the types of organisations. From regulator to device design, device design to consultant, supply chain to consultant. Whilst this presents an analytical challenge to assessing the nature of relationships and knowledge sharing in Wales, the transfer of expertise and insight into the innovation process is apparent. This activity draws upon the clustering principles highlighted in the literature review (Maskell and Malmberg, 1999; Owen-Smith and Powell, 2004; Martin and Sunley, 2006); this is likely to become more commonplace should developers become increasingly embedded in Wales.

Where the employees of disbanded technology developers operated on a consultancy basis, knowledge was retained within the MEIW. One such individual highlighted personal motivation.

> “If I don’t pass this information on, what have I achieved for 10 years at the coal face? At the same time, many of the staff have left the MEIW so a lot of knowledge has been lost, I still give them a ring if I need an answer. Of those, there is only myself that’s from Wales. Everyone was brought in to bring it all together, as soon as it all went wrong, they left. The knowledge is still there in the industry and we report it as best we could."

This could be considered an insight into the availability of skills and expertise found in Wales. Where this may provide insight into the extent of technology embeddedness it also outlines the difficulty in supporting an innovation pathway when there are setbacks. This suggests the pivotal role of knowledge sharing in order to support the longevity of innovation knowledge.

6.6 Discussion of innovation support in Wales

As can be seen during this chapter, there are extensive activities in Wales to focus on innovation and promote change at both a governmental and industry level. . There is a tendency towards collaboration on the part of the government, over the postulated government-driven activities to render the region attractive to developers. With respect to events that signal the development of technology and the wider industry, Table 6.1 highlights those that support innovation. Events in bold can be considered failures within this aspect of transition.

Year	Month	Outcome
2013	Feb	TD6 consented
	Feb	TD6 receives funding from UK Government
2014	Aug	TD4 device officially unveiled
	Oct	Directional Waverider buoy launched in Pembrokeshire
2015	Dec	TD4 installs off Pembrokeshire Coast
2016	Oct	**TD4 in administration**
	Dec	TD1 constructing WaveSub
2017	Mar	TD5 begins sea trials for Wave Rower
	Oct	TD1 unveils quarter-scale WaveSub for sea testing
	Nov	MEW wins award for 'Outstanding Advocate' at Green Energy Awards
2018	Jan	TD1 WaveSub at sea for initial stage of testing
	April	Marine Hub and MEW collaborate, funded by the WG
	Sept	TD3 deploy utility-scale device Anglesey
	Oct	TD3 generates electricity
2019	Oct	First Wave licence in Wales granted to Bombora

Table 6.1. Technology support outcomes in Wales.

Source: Author's own.

The notable example of innovation support failure is TD4 going into administration. As the chapter has highlighted, this is a result of several factors including the balance of public and private cash flow. This shows that the provision of grant support does not always lead to success. It is also possible to surmise that no technology developer will be able to progress in the industry without independent financial capacity as this is required to secure grant funding. However, it can be noted that over this time there have been few innovation support failures, although much of the activities towards generating the foundations of a successful technology are supported by the industry utilising EU funding over the intervention of the WG.

In this light, there seems to be an emerging interplay between WG adopting a guiding role in encouraging the industry, whilst at the same time not truly engaging with the areas where most support is needed. Interviewees believed that the focus on creating jobs and growth, rather than innovation that leads to growth was as a result of the economic history of Wales and a desire to "fill the void the private sector had left" (GV3). In this respect, it can be surmised that the WG is undertaking activities to render the MEIW an attractive prospect for governmental aims over making the region attractive to developers. However, this is problematic as innovation literatures highlight that the best economic outcomes result from an industry that is engaged and conducts many of its activities within a region.

Through WG's attempt to influence the market rather than providing early-stage support and allowing market forces to continue to drive technological development, there were technologies that were missing out. One such technology was a tidal-lagoon device, which was unable to secure grant funding for the early stages of development due to a lack of match funding. However, this technology had already secured £billions in private investment for later stages of development, but the type of investor with which they engage "only deal in billions, not millions" (TD2). This is an interesting gap in support, as arguably the WG is supportive of lagoon technology due to its continued focus on the Swansea Bay Tidal Lagoon.

Indeed, it is notable that Swansea University as part of SEACAMS undertook numerous case studies focused on the Swansea Bay Tidal Lagoon (six out of twenty-three project case studies listed). The dominance of this technology in Wales shows the constrained path creation that may explain why there is little to no operational ME in Wales. Success is being constrained by the criteria imposed on technology, where the pathway that is available to the overall industry is limited by the need to both innovate a successful design and meet the demands of the governmental criteria. At the same time, the availability of regional development funding and the prospect of jobs continues to contribute to the support of this large-scale technology despite limited progression in deployment. Further, the overall financing of the project was not within the capacity of WG and therefore the Tidal Lagoon could be considered a high-risk technology, given its high initial costs and dependence on market support. Whilst all these factors can contribute to supporting projects and developing momentum, the 'picking of winners' evidenced in market creation continues within innovation support.

The utilisation of regional development funding introduces a duality in the transition pressures the WG exerts. It would seem that despite the 'jobs and growth' focus of market creation activities leading to support for large scale technologies, support is still provided for the modular technologies to innovate. This might suggest an aversion to risk which the WG is trying to mediate, recognising regional development issues whilst simultaneously seeking to promote innovation. At the same time, however, without sufficient political support modular technologies will have a more difficult route to market. This signifies a need on the part of the government to understand the measures that should be implemented to give consistent signals to the industry that there is potential for a burgeoning MEIW. In an absence of both innovation support and legislation that will create a market for ME technology in Wales, then it becomes more likely that the MEIW will fail.

The evidence suggests a tension and skill in balancing partiality. Technological and spatial partiality is required to pursue or embed technologies that are innovative and create a high number of jobs. There are also pressures for impartiality, for example in relation to requiring competitive tendering and the practices instituted by WEFO. At the same time, the 'best practice' followed by WEFO does lead to a loss of social capital as supply chain companies may not be successful in subsequent tendering rounds. Social capital is increasingly shown to be integral to the innovation and transition process, where the evidence shows that network organisation and collaboration at a local level supports these changes. TIS literature further highlights the importance of local networks in the early stages of innovation (Lundvall, 1988). In response, developers utilise private funding to create flexibility, suggesting a need for grant funding that demands elements of best practice and the flexibility for developers to utilise private funds to 'select' suppliers. This has positive impacts for social capital development and knowledge sharing, the approach will also ensure that developers encounter a wide range of suppliers and have the opportunity to foster stronger connections.

The evidence presented also shows that Welsh policy has a particularly strong focus on reducing costs, and this was considered by the industry to fuel a need to overpromise on returns in order to secure financial support. This is a well-observed phenomenon in megaprojects that are inherently risky due to complexity and long planning timelines (Flyvberg, 2006), but need to persuade others to support them. Outcomes include cost over runs, delays and "benefit shortfalls that undermine project viability during project implementation and operations" (Flyvberg, 2014, p.9). In the case of the ME industry, it can be concluded that this narrative will take place over a long timeframe due to the intersection of innovation and transition, coupled with the demands of actors that are exogenous to the industry, such as WG and a desire for economic growth.

It is notable that alongside a need to provide support for innovation, Welsh policy identifies that infrastructure requirements such as landfall and sub-station works are not economic for individual project developers to fund. This builds towards the pertinence of the demonstration zones where the WG can easily influence industry development and contribute to local knowledge network development. However, these features are driven by exogenous rather than endogenous actors, with limited activity on the part of WG to facilitate this infrastructure development. These features will be fully explored in Chapter 7 but suggest that there are multiple layers to the transition mechanisms utilised by the WG in an effort to progress the industry and to do so more specifically in Wales.

In contrast to the aim of the WG to create jobs and growth, the universities seek to generate technical knowledge. This is a complementary mechanism in that it narrows in on technology and regional environmental monitoring design, an area outside of the expertise of other actors in Wales. These symbiotic goals could potentially promote industry transition. However, the closed nature of the WG and university networks with limited co-operation between the actors strongly suggest a need for intermediation in Wales. This intermediation should facilitate social capital development and knowledge sharing to ensure the diffusion of the expertise that is developed by these regional actors but fails to be fully shared with the innovation actors that most require this expertise. This said, there are efforts to support individual actors, but the translation of this to making the entire region more attractive is limited.

The opportunity for Wales lies in the ability to foster small-world networks with dense local clusters. The MEW demonstrates this intermediation through actions such as emailing the supply chain and developers following foreclosure of the disbanded technology developer "to emphasise employees should be snapped up before they left the industry" (TD5). It could be suggested that the presence of these actors becomes necessary due to the weak implementation of whole industry thinking on the part of actors such as the WG and the universities.

Significantly, the development of the MEIW and generation of innovation support mechanisms is also driven by a large amount of grass-roots work. This was not foreseen based on the literature review hypothesising. There are many actors who provide their services for no or nominal cost with the understanding that the MEI is at the early stages of development. These organisations supplement their MEI activities with the profits from other areas, relying on social capital and the customer's experience of their knowledge capabilities to ensure a continued relationship. This could be thought to narrow the number of potential supply chain companies, as not all will have the capacity to engage in this way. Whilst technology developers can purchase the services of some of these supply chain companies, utilising private or grant funding, there is no evidence of grant support for knowledge acquisition by supply chain companies.

Alongside this possible lack of capacity for appropriate supply chain companies to engage with diversification into the MEI, it is apparent that the diverse range of skills demanded of developers also impact the innovation process. As the chapter highlights, engineers are being asked to be project managers. Moreover, some of the actors previously mentioned for their nominal cost charging are also supporting developers in producing business plans. Whilst on the one hand, this suggests a high level of social capital and collaborative support within the industry, on the other this introduces a great deal of risk to the developer in terms of dishonest practice.

TIS theorising asserts that there is no necessity for niche actors to push into the regime (Hekkert and Negro, 2009). However, the evidence suggests that the actors in the MEIW are adopting this type of role, advocating for ME and the progression of activities in Wales. Arguably, MEP and MEW compensate for many of the measures that are not undertaken by the WG, displaying path-creating tendencies in the context of WG's path-dependent tendencies. As this and the previous chapter have established, the MEP and MEW work as intermediaries connecting actors and knowledge using multiple methods.

Furthermore, as organisations they also build upon 'outside' sources of knowledge by engaging with organisations to undertake learning. Whilst MEW is sponsored by the WG, anecdotal evidence suggests that MEP was largely ignored by the WG until sufficient momentum had developed. What is evident is that MEP operated with regional development goals in mind: when this is coupled with the use of regional development funds to support innovation, questions arise about the role of technology embedding in supporting sustainability transition.

Chapter 7 Technology Embedding

7.1 Introduction

This chapter will evaluate how well marine energy (ME) technology has become established in the Welsh economy and how actors contribute to this change. The innovation support chapter highlighted how regional development funding supports innovation, suggesting an imperative to integrate technology demands within the regional economy to maximise economic development outcomes. The research aims to better understand how actors support these processes and whether this in turn contributes to industry transition. This chapter will present the evidence of the integration of ME in the regional economy, which could be considered a pre-cursor to sustainability transition and will further highlight the role of geographical constructs.

The evidence of embedding will initially be addressed at a Wales level to understand the framework that actors negotiate. Many of the actors that engage in these activities have been considered in the market creation and innovation support chapters. All-Wales developments are driven by actors such as the Welsh Government (WG), Welsh European Funding Office (WEFO), and the Crown Estate (CE). However, as the evidence below will show, the availability of different types of marine resource led to varying conceptualisations of the 'region' with which actors engage. A comparative evaluation of the NUTS3 regions, Pembrokeshire and Anglesey, will provide insight into the different strategies of regional networks to engage with energy transition, outlining influential regional characteristics.

7.2 Aims and effects of regional development goals

The analysis thus far has established that Welsh policies emphasise the maximisation of benefits to Wales from any energy technology development (Welsh Government, 2012c). This ethos is predicated on the economic difficulties that are being experienced by the country due to declining industry, the global recession, and increasing pressure from the Brexit process. Increasing levels of unemployment introduces a demand for a high number of jobs that are of good quality.

The ME sector is regarded as a high value-added sector that has the potential to enhance GDP and employment - factors that contribute to a desire to influence industry development in Wales. As highlighted in the investigation of innovation support mechanisms (Chapter 6), much of the public money available to support technology development stems from regional funding, specifically that of EU convergence funding. The lack of independent WG money to invest becomes apparent with statements such as "we will work closely with potential developers who are capable of financing the project privately" (Welsh Government, 2012c, p.22).

These regional development issues have meant that convergence funding can be accessed by WG and is applicable to much of Wales, particularly the two NUTS3 regions where the main ME resources have been identified. As alluded to previously, this funding carries with it certain constraints that are aimed to promote regional development. This is where WEFO has a particular influence on the industry: where the previous chapter considered the impact of the EU funds (dispersed pre-Brexit) on technology, this section will consider the role of WEFO as an actor that disburses funds and mediates expectations within Wales.

7.2.1 Wales European Funding Office (WEFO) as an actor

The convergence funding utilised within the MEIW has several associated conditions in order to integrate benefits into the respective economy. The guidelines are found in an extensive document entitled 'Eligibility Rules and Conditions for Support from the European Structural Funds 2014-2020' and are enforced by WEFO. This document makes explicit the geographic area eligible and the implications of this for the industry. Where activities are "to be implemented within the programming region that provides the funding" (WEFO, 2016, p.68), up to 15% of the value of the ERDF funding is available to organisations outside the region provided benefit can be shown for the convergence region.

Interviewees highlighted that the convergence funds have made Wales attractive to their organisation (TD3, TD5) particularly when added to the marine resource and proximity to grid connections. A further developer was attracted to the region from Australia based on the funds available. Companies outline how "having £100 million to spend on marine energy is a massive statement and has seen our work really accelerate" (TD4).

The evidence does show, however, that developers are easily able to change location, leaving regions vulnerable when the actors may be present due to a pursuit of funding and continue to search for opportunities elsewhere. As a result of the convergence funding "there are developers who entered the market in Scotland who will now be going to Wales" (SC4). There is a risk that these 'mobile' developers could equally leave Wales should better opportunities become available elsewhere. Indeed, the Australian developer demonstrates this mobility across continents. Therefore, the embedding activities and regional ‘extras’ become increasingly important to avoid this outcome.

It could be argued here that actors such as MEW play an important role in furthering a developer’s interest in Wales by inviting them to working group meetings. In the one day of a working group meeting the organisation can meet a whole range of parties and "essentially it saves weeks of someone's time" (GV2). As a result of this interaction, some developers will realise the region is “not for them”, others will continue to develop their interest and locate within the region (SC5). Importantly, these interactions with developers all represent opportunities for knowledge transfer. This also begins the process of integrating the actor with the knowledge network where sharing of ‘outside’ information may take place, all contributing to the ongoing development of the industry within Wales.

Interviewees opined that "without Structural Funds Welsh Government couldn’t afford to put this level of money behind the sector as it would probably be seen as too high a risk"

(TD3). This highlights that the less-developed nature of the region may be problematic for ongoing industry development and places an onus on the effective utilisation of remaining funds. Whilst the positive outcomes of attracting developers to the region are apparent, regionally, the withdrawal of the UK from EU presents multiple levels of risk. From the Brexit referendum onwards, WEFO operates in a time of uncertainty, both in terms of continuity of services post 2020 and the likelihood of businesses applying to access funds.

There are, however, concerns as to the utilisation of these funds to support the MEIW in lieu of other grant funding mechanisms. That the significant level of funding was not managed by a specified team with any technology expertise to ensure maximum efficacy of the fund was a cause for concern amongst interviewees. Further, difficulties were encountered by the developers as without a specific team, interactions were with different WEFO individuals and the same query often generated vastly different responses.

Developer interviewees also criticised WEFO for the strictness with which the guidelines were adhered to, highlighting that the right supply chain company was not always available within the region or Wales. Whilst interviewees were aware these guidelines existed for regional development purposes; they were considered problematic for an industry in the early stages of innovation. One interviewee cited the history of EU and public funding in Wales, where there was a:

> "culture of the public sector thinking it can create jobs and growth" (GV3). GV3 credited government's role to "facilitate, enable, de-risk and put infrastructure in place to enable the private sector to succeed".

This suggests that some of the postulated path dependence tendencies are present in the region, with a public sector that traditionally seeks to steer the development of an industry within the region. Yet the evidence suggests that bounding a region based on bureaucratic borders does not match the geography of the innovation system (Jehling et al., 2019). This is perhaps especially the case when the sector is emergent and there is no existing evidence of its geographical and economic reach. This could be considered a fundamental contradiction in the utilisation of regional development funds to support nascent technology. This said, without this funding Wales would be unable to attract developers with financial incentives, as the region's financial capacity as a less-developed region is limited.

The contradictory nature of utilising regional development funds is further exacerbated by the EU-mandated timeframe within which funds need to be dispersed by WEFO. At the MEW industry event 2019, one of WEFO's main methods of communication with the industry, the WEFO speaker highlighted that the newness of ME technology made it difficult for applicants to forecast project times. When this is coupled with the lengthy application process highlighted by interviewees, risk is introduced in ensuring that these funds are fully enjoyed by the MEIW. This introduces another temporal aspect that developers must manage and align.

The MEI funds need to be spent by December 2020 and "it's quid pro quo, you need to help us to spend money, but you must contribute towards the objectives" (Ryland, 2019). This may potentially influence which marine technologies are funded; those organisations that have already secured funding are better known and more able to prove that they will meet spend deadlines. Furthermore, technologies that are at a higher technology readiness level will more quickly utilise these funds throughout the supply chain, and so are better able to meet within-region spending requirements. These two factors may disadvantage those developers that are at an earlier stage of their innovation process.

The parameters that come from the EU with the conditions of grant spending also introduce another layer of complexity in the governance of transition in Wales, meaning that the 'quick win' technologies are more attractive to WEFO within this framework. However, contributing additional funding to organisations could be thought to increase the likelihood of the developer embedding in the region. The longer a developer is present in the region, this allows greater opportunity for further integration within the supply chain and the development of social capital.

What emerges from this evidence is that WEFO has a critical role in mediating the expectations of the EU with respect to convergence and the needs of the MEIW. In this way, WEFO is an actor that influences the industry trajectory in Wales through a multi-faceted role of administering funds and supporting the embedding of technology in a variety of ways. Much like CE and NRW's dual roles, WEFO influences the industry both as a regional institution and an intermediary with technology embedding aims. WEFO's influence spans Wales as whilst the ME resources are in convergence zones, the socio-technical arrangements to exploit these resources and create a new innovation system have a wider reach. There are, however, other initiatives to encourage technology embedding which will now be considered in greater detail.

7.3 All-Wales technology embedding developments

7.3.1 Introduction

Alongside the convergence funding that may attract a developer to the two key NUTS3 regions where the MEI is developing, there are further all-Wales activities that seek to promote technology embedding which is hypothesised to support innovation and transition through co-location and knowledge sharing. Driven by CE, the demonstration zones initiative seeks to accelerate the innovation process and at the same time embed the technology. However, activities of the WG provide varying support for different technologies, where large-scale is seemingly preferred to modular. This has the potential to influence the type of technology that embeds in Wales and the regional benefits that are drawn down. At the same time, industrial decline introduces supply chain influences that impact the ability of developers to access support within the regions. This becomes more notable when coupled with convergence funding.

7.3.2 Demonstration zones to overcome consenting issues

In 2014 CE announced the agreement of seabed rights for six new wave and tidal current demonstration zones across the UK. It can be seen throughout the analysis chapters that

CE undertakes a range of activities to encourage the development of the industry. The CE interviewee stated that the demonstration zones were devised to enable transfer of activity ownership to the local community, including subletting of the seabed. This is with the aim of accelerating technology development. The managing organisations secure consent for development through undertaking the necessary environmental assessments and community consultations. After securing consent, infrastructure will be constructed that developers can “plug into” (GV1), smoothing the pathway to commercialisation. Third party managers from the locality therefore have extensive responsibility but the CE does not transfer all powers as “we need to be comfortable with what they are doing” (GV1). This shows the CE’s desire to ensure accountability and maintain a degree of control, connected to their remit to ensure returns to the Treasury.

Interviewees estimated that the demonstration zones are “the Crown Estate’s way of trying to move the sector forwards and start thinking about arrays” (TD3). This scaling up is required to contribute sufficient electricity to the grid. This makes the initiative particularly important for technology embedding as alongside the desire to promote innovation, establishing the groundwork for arrays increases the likelihood of developers remaining in situ.

Two timeframes have been issued for demonstration zone development in Wales. Pembrokeshire seeks to achieve consent by 2022, infrastructure by 2024 and installation of first technology in 2025 (Wave Hub, 2020). Anglesey seeks to establish consent in ‘the second half of 2020, on land infrastructure by 2022, and offshore infrastructure to start in 2023 (Morlais, 2020). In Anglesey, WG are contributing to the initiative through funding 50% of cabling costs which are estimated to be the most significant portion of the cost in Anglesey.

The setup of the two demonstration zones varies quite significantly. In Pembrokeshire, the zone is managed by Wave Hub Ltd a company that also manages a test site off the north coast of Cornwall and the North Devon Tidal Demonstration zone. It could be questioned the extent to which ownership is transferred to the 'local community' where the selected third party manager is not from within Wales. This said, this actor will bring knowledge to the region. In particular, the original Wave Hub site was ERDF funded, meaning that the organisation has experience of engaging with innovative ME technology in a less-developed region.

Wave Hub Ltd.'s involvement highlights that there is great potential to enjoy the learning undertaken by non-local actors or 'global nodes' at other sites. The demonstration zone will house three wave technologies that had not been announced in 2020. Wave Hub Ltd will also collaborate with Marine Energy Wales (MEW) to deliver the project, and the evidence shows the extent and detail of local knowledge that can be provided. MEW's involvement makes it more likely that local supply chain companies will be used due to extensive knowledge of operations within the region.

Conversely, the West Anglesey Demonstration Zone is managed by Morlais. Morlais is a subsidiary of Menter Mon which is a not-for-profit based on Anglesey Island that works on a sustainable future for rural organisations. This means that the organisation has knowledge of the local supply chain but not of operating a marine technology testing zone. The website has published a list of the seven agreed berth holders, but none have existing operations in Wales. Two are headquartered in Scotland, three in America and one in Canada.

Perceptions of the likely impact of these two differing NUTS3 regional set-ups for the demonstration zones will be considered more fully in the regional sections. The regional contexts will likely influence the development trajectory of the wave and tidal technologies, yet there are also other technologies that interact with the collective development of the MEIW and are considered next.

7.3.3 Interaction of multiple technology trajectories

As noted at points in this analysis, there is a recurring narrative of comparison of ME with other RETs, yet within MEIW there is also the comparison of the Swansea Bay Tidal Lagoon against the wide range of modular technologies. There are many in the industry that feel that the attention Swansea Bay Tidal Lagoon receives has the potential to overshadow other marine technologies. A range of interviewees expressed this concern, with the Swansea Bay Tidal Lagoon having the potential to be "the nuclear of our industry" (TD3) as the large power capacity would crowd out support for other modular technologies.

The Hendry Review (2016) was a UK Government commissioned report to explore the viability and power potential of tidal lagoon technology. The report states that the technology has the potential to compete with nuclear technology whilst being an RE resource. Notably, it is the only government-affiliated document that explores a sole technology. The modelling takes into account the lifespan of technologies and the "impact on consumer bills of large-scale tidal lagoons appears attractive, particularly when compared to nuclear projects" (Hendry, 2016, p.85). This is significant as whole-of-life accounting of nuclear including decommissioning and toxic waste can make the case for RETs rather than 'low carbon' that much more powerful. This mode of analysis is counter to much of the short-termism utilised when comparing the cost of other ME technologies.

Whilst the Hendry Review was a UK Government report, in the short- and medium-term Wales would have been the main benefactor due to the pathfinder project being located in Swansea with many other lagoons proposed in Welsh waters. This type of modelling would be positive for other technology types. However, the costs and capacity for this type of modelling is likely to be prohibitive for developers that are in the process of developing a commercial technology. That this study was commissioned by the UK Government without similar studies for other technologies again suggests the lack of symmetry of support for technologies, a key criticism that was apparent in the market creation analysis.

In an embedding context the Hendry Review is significant, due to the significant level of support that the Swansea Bay Tidal Lagoon has gained in the political sphere. It has been cited by the WG and other organisations as evidence that the UK Government should support this technology. However, the lack of co-ordinated support for other technology types potentially indicates the lack of political will to accelerate ME technologies in Wales.

The feature of the Swansea Bay Tidal Lagoon that has captured political interest is that energy generation is interwoven with regeneration and leisure prospects for a declining industrial region. Although entailing a far greater modification of the physical environment than other ME technologies, Swansea Bay Tidal Lagoon has achieved a greater degree of embedding in the Welsh political mindset. In contrast, the modular technologies that are funded by regional development monies have been constrained by extensive consenting demands.

It is perhaps this high degree of embedding that makes the Swansea Bay Tidal Lagoon project particularly attractive as it has become marketed as something belonging to the community where leisure pursuits such as sailing could also be undertaken. This perhaps explains the somewhat different engagement to a proposed tidal lagoon in Anglesey that integrates flood defences. TD2 highlighted that whilst the technology itself is expensive to develop and install, it would serve multiple purposes. The interviewee called into question why there is no remit that covers dual utilisation of a technology: TD2 generates energy, acts as flood defence, and creates a significant number of jobs.

At the NUTS3 regional level there are goals to link innovation with regional development, thus interviewees expressed concern that lagoon technology may remain the primary political focus. This evidence suggests a tension between funding and political support for technology within Wales and powerful pressures working against alignment. EU funding is used to support the modular technologies, yet the political support seemingly is for one large scale technology in particular. This suggests a limit to the political ability or desire to support a range of technologies, which will ultimately slow the rate at which transition occurs.

At the same time, tidal lagoon technology uses no novel concepts perhaps making it more palatable by reducing technological risks. When adding the somewhat contradictory point that consenting ability for this large technology lay with the UK Government until early 2019, and the financial capacity to support this technology is not available to Wales as a less-developed region, the reasoning becomes less clear. This suggests that there are significant differences in the interests of parties promoting the different technologies.

However, some developers considered that there was sufficient space for all types of technology to co-exist in Wales as they would not be considered direct competitors. This could be considered the hope, but the wider evidence exposes a range of tensions in this prospect. The difference in the scale of construction and funds required were viewed as important as developers would not be “vying for the same pots of money...We’re looking for millions, they’re looking for billions. They’re going direct to central government, we’re going to WEFO” (TD3).

Going forward the evidence suggests that promotion of Swansea Bay Tidal Lagoon as a regeneration ‘lifestyle choice’ for the region may more deeply entrench the coupling of technology innovation and regional development. This could be considered both positive and negative. Where innovation provides the potential for regional economic development, the promise of energy, employment and enjoyment from the tidal lagoon sets possibly too high a baseline for nascent technology development to match. Indeed, it could be said that the Swansea Bay Tidal Lagoon over-promised and under-delivered as the project has not gone ahead.

Alongside the developing trajectory of tidal lagoons, the evidence thus far has highlighted two main trajectories of economic decline that are energy-related: nuclear in Anglesey and oil in Pembrokeshire. There is one other notable trajectory of decline in Wales which is the steel industry. A number of interviewees (TD1, SC1, SC2, SC5) sought to link the potential of a burgeoning MEI to supporting the steel industry as developers demand raw materials. Yet there are those (SC10, SC12), who estimate the economic prosperity from ME for Wales comes from the operation and maintenance of the technologies rather than manufacture. This observation is at odds with convergence funding goals of indigenous supply chain strengthening.

SC12 highlighted that there is an oncoming skills shortage in Wales and across the UK, particularly in certifying steel fabrication work. This is due to the need for the certifying individual to have decades of experience, and confidence that the fabricator had sufficient skill and experience to do the task. One such qualified person stated that "I wouldn't put my name on a certificate guaranteeing for 25 years the work of someone who has just qualified". Furthermore, the "good fabricators will go where the money is, which is the nuclear sector rather than marine".

The evidence around steel certification and marine warranty surveyors suggests that there is an issue of spatially dispersed people who provide technical oversight in the ME innovation trajectory. It could therefore be suggested that where regional development efforts will seek to embed manufacturing capabilities within the region, without sufficient long-term skills planning the capacity within Wales to support these supply chain activities may not exist. This poses another potential risk to embedding the technology and would necessitate developers accessing these skills elsewhere, opening another potential link to leaving the region. This then places increasing importance on the activities that are undertaken to support technology embedding.

Further to this, some developers highlighted that the UK political backdrop of Brexit had made the domestic UK market for ME difficult. As a result, companies are looking to export expertise elsewhere: developers are considering island nations, where the cost comparison would be against expensive imported diesel and security of supply; knowledge organisations seek markets where there is an "open door to develop" (SC4). However, "there's an appetite in Wales and the stuff that's going on is quite dynamic" (SC4) and this may have the power to retain organisations within the region when coupled with the availability of funding. Yet where regional growth goals are achieved or Brexit takes away these funds, then embedding these technologies may become a more difficult task. This suggests that regional decline trajectories and how actors engage with the MEI to counter this is increasingly important to the ME trajectory. The two regions in Wales provide insight into strategies adopted and allows comparison of the outcome.

7.4 Comparison of regional approaches

7.4.1 Overview

The small size of Wales was credited as an opportunity to "join up the dots and show where organisations could contribute to the supply chain, and through the product lifecycle from conception to mass production" (GV3). In this way it would be possible to identify where the WG could add value and what should be left for the private sector to address. This would support technology development and optimise the embedding of the developers as their needs would be met over the course of the technology development. Such a system would increase accountability and play on regional comparative advantage:

> "We've always created jobs and growth from the sea, this is just a new way of doing it based on the way technology and R&D has gone" (GV3).

However, in Wales two different regional approaches to supporting ME innovation and embedding of economic development benefits can be observed. Where the best opportunities in the RETs market will be for "those regions that have first developed an integrated supply-chain with appropriate technical skills and academic support" (Welsh Government, 2012a), comparison of these approaches will provide additional insight.

These regional approaches are within the framework of the UK Government industrial strategy, that:

> "plays to the Government's longer-term cautionary approach, but unfortunately

acts as a wedge between regions as they and the various renewable energy technologies compete for funding and respond to Westminster policy" (SC7).

The logics of this competition have mixed effects on how innovation, economic development and the ‘region’ interact. This industrial strategy was considered to be divisive in the industry and that "there needs to be a chance given to smaller industries that could be really UK-owned" (GV2). This section considers strategies to pursue these goals.

7.4.2 Pembrokeshire

7.4.2.1 Overview

In Pembrokeshire, the ME resources favour the development of wave technology, with modular technologies in the development and testing phase. The modular technologies include Marine Power Systems, Wave-tricity and more recently Bombora. Alongside these wave technologies there is the possibility of Swansea Bay Tidal Lagoon.

Pembrokeshire Coastal Forum, founders of MEP, accessed funding through the WG’s ‘Rural Communities – Rural Development Programme 2014 – 2020’ to scope the supply chain for ME in Pembrokeshire. The development of this report highlights some of the tensions of developing a supply chain in a new industry. The original plan was to map Pembrokeshire only as the developers who had built and tested their devices in Pembrokeshire had found 50-60% of the supply chain locally. However, the first stage of assessment identified companies throughout South Wales that were able to supply the MEI in Pembrokeshire. It was concluded that many of these 268 companies were unaware of the potential to contribute to the MEI, and as a result supply chain events were held to highlight the potential. This shows the difficulty in mapping the supply chain in an emerging industry, and as such it was not possible to develop a full list for the region.

There are, however, actors that come to the fore in the industry for driving change and engagement with ME. These main actors in Pembrokeshire include MEP, MEW, and the

Milford Haven Port Authority, whose activities have been considered in both the market creation and innovation support evidence. Here it is important to address how these actors have impacted technology embedding. There are multiple streams of activity instigated by the organisations including the development of a Marine Energy Hub, the Marine Energy Testing Area, and supporting the development of the demonstration zone. These are factors that could lead to cluster development and these actors have also contributed to the inclusion of Pembroke Port in the Swansea Bay City Deal initiative.

The projects initiated by these actors support multiple facets of innovation such as knowledge sharing, technology development and testing. MEP found that other regions did not replicate the co-ordination strategy adopted for demonstration zone development, despite "Wales's advantage of size, without too many layers of bureaucracy to get to speak to the people you need to" (SC6). Whilst the influence of Wave Hub Ltd will increase with the development of the demonstration zones, at the time of field research in 2016 - 2019 the organisation’s engagement with the region was limited.

In Pembrokeshire, regional activities can be summarised as the building of a community drawing on cluster and knowledge network principles to support the MEI. There is recognition that without timely action skilled people will leave the region in search of jobs and it "will be too late” (SC5). The MEP interviewee highlighted that a lot of skilled people were leaving the region and young families behind, "so if we can grow this and keep people here, this is the best opportunity we've had in decades." This further highlights the regional characteristics that influence transition and how the development of the MEI in this region is occurring in the context of constant change.

7.4.2.1 Regional decline and MEI support

Previously around 20% of the UK’s energy supplies were received via Pembrokeshire in the form of oil (Business Wales, 2020a), with decline in this industry impacting the region’s economic development. WG developed Enterprise Zones in 2012 with the aim of creating “the best possible conditions for your business to thrive” (Business Wales, 2020b). There are eight enterprise zones across Wales, each with its own sectoral focus and a range of incentives such as financial assistance, accelerated planning processes, and competitive property cost. Each zone has a board which is led by the private sector and directly advises the WG and its ministers.

The Haven Waterway Enterprise Zone in Pembrokeshire is based on existing and potential new energy sites, with a ME focus. The zone supports companies from other sectors to locate and expand, and a growing supply chain is hoped to be positive for the development of the MEI in the region more generally. Enterprise zone status shows that Pembrokeshire has prior experience of traditional strategies for attracting investment for development and is another actor for the MEI that “adds weight and strength to the area" (SC5). Associated business rate relief available for companies within marine renewables was not credited for companies relocating but that the oil and gas work "drying up" meant companies lost "bread and butter work" (SC6). As a result, many of the supply chain companies were particularly interested in the Swansea Bay Tidal Lagoon due to the large-scale demand for skilled labour that would likely reach Pembrokeshire.

In the estimation of some interviewees the skills required for the MEI are not particularly different and that "the traditional hydrocarbon sector is just moving their skills over to another sector" (SC6). Indeed, this is supported by the Pembrokeshire Coastal Forum’s supply chain report that highlights the large number of companies that have the potential to contribute to the MEI.

Following the creation of the Haven Waterway Enterprise Zone, the City Deal initiative was announced by WG. Signed March 2017, The Swansea Bay City Deal is an investment of £1.3bn in 11 major projects across the Swansea Bay City Region made up of Carmarthenshire, Neath Port Talbot, Pembrokeshire and Swansea. The funding is a joint venture between the UK Government and WG (£241m), the public (£396m) and private sector (£637m). Over a period of 15 years the Swansea Bay City Deal is forecast to boost the regional economy by £1.8bn and create 10,000 new jobs. This initiative will support Pembroke Dock Marine to:

> “create a world class marine energy and engineering fabrication, test and deployment hub, delivering the support and infrastructure needed to further grow Wales’ blue economy” (Swansea Bay City Deal, 2020).

The inclusion of Pembroke Port Marine in the Swansea Bay City Deal is significant for technology embedding as it recognises the potential of developing a cluster in the region. The goal of the initiative is the decarbonisation of energy production including early stage and commercial scale test sites, and industry-focused port infrastructure. This provides a locale to accelerate the technology and the 15-year plan for investment is a longer time period within which developers and other supply chain companies can become embedded in the region.

As an existing regional actor with a significant involvement in the oil and gas industry, Milford Haven Port Authority contributes significantly to the embedding of developers. As highlighted previously, Milford Haven Port Authority is a trust port with a long-term duty to protect the interests of the shareholders. The relationship between regional actors such as MEW and Milford Haven Port Authority has contributed to the flourishing of the ME community in Pembrokeshire.

TD5 outlined how integral Milford Haven Port Authority are in supporting their technology through signing a ‘Memorandum of Understanding’ and supporting without charge where possible. The developer went on to highlight that there was no place in the UK like the ‘pickling pond’ where "you can go and dunk your piece of kit...that's where Pembroke Port is unique". This casual way of interacting is very beneficial to the industry and is facilitated by the control Milford Haven Port Authority has over spaces within the port, coupled with financial autonomy. Milford Haven Port Authority’s attributes resulted in the developer seeking to do "as much as we can to encourage marine energy by building the device down there and supporting the supply chain". The developer confirms Milford Haven Port

Authority's strategy to attract developers where "the Port will provide services as much as they can gratis to developers and this in turn supports infrastructure development".

Built over many years, there is significant social capital between MEP and Milford Haven Port Authority, support by the Milford Haven Port Authority's organisational ethos, sponsorship of the MEP, and the history of MEP staff members having previously worked for Milford Haven Port Authority. This history has culminated in the development of a joint initiative, The Marine Energy Hub, where the aim is to have no physical barrier to connecting with other organisations; "you can just wave your hands in the air and ask a question about any subject" (SC5). This is a model of working that is increasingly observed in digital technology hubs where shared workspace is used to facilitate rapid knowledge exchange and foster cluster-type outcomes. The venture is an extension of MEP's knowledge sharing capacities and seeks to strengthen Pembrokeshire's offer to the sector.

The activities detailed in this section highlight some of the additional key actors in the region that contribute to industry transition alongside the much-discussed work of MEP and MEW. The Haven Waterway Enterprise Zone and Swansea Bay City Deal are designed to encourage regional development and Milford Haven Port Authority's activities seek to compensate for the volatility of its principal sector. There are, however, further activities to support the testing of technology, which could be considered the unique strategy of the region when compared with North Wales. This is important as initiatives such as the demonstration zones could be considered support from high-level institutional actors that is appropriate only for technologies that are at a mid-level of technology readiness.

7.4.2.2 Focus on testing

2012 policy highlights the existence of testing facilities throughout England and Scotland, the policy does not identify a need to develop a testing site within Wales. Interview discussion also did not identify a need for a formal testing centre within Wales, with views that a testing facility was not necessarily integral to industry development. Overall, developers highlighted the generally short time frame that 'tank testing' is utilised for, indeed one developer used a facility for a single day.

However, there are other activities to promote testing capacities including the Marine Energy Testing Area which is a £1.9 million project supported by the WG (£1.2m), the EU, the Swansea Bay City Deal and money from the Coastal Communities Fund. The wide range of funding sources suggests the large number of organisations that have a vested interest in the success of ME in Pembrokeshire. The aim of the Marine Energy Testing Area is "to provide early-stage device developers with an easy access testing facility to de-risk future deployments and drive down the cost of energy" (META Wales, 2018).

The Marine Energy Testing Area forms part of the Pembroke Dock Marine project as part of the Swansea Bay City Deal that is separate to the 'pickling pond'. Importantly, unlike other testing areas in the UK the aim is to operate on a dynamic basis where testing need not be booked in many months in advance. This would allow quick monitoring and evaluation testing, allowing developers to "repeatedly deploy at low costs, learning lessons quickly to accelerate the path to commercialisation" (SC5). This could be considered an important step in accelerating the innovation process.

This evidence suggests a contradictory narrative to that established in the interviews and policy where testing is not regarded as important to Wales for industry development. Therefore, the development of these facilities could be conjectured to have the purpose of supporting technology embedding. Indeed, the development of the Marine Energy Testing Area is a collaborative process that utilises knowledge from different regions, with press releases entitled "Scotland and Cornwall to assist in development of Welsh Marine Energy Test site" extolling the benefits. Future social capital and knowledge sharing is evident with Wave Hub Ltd, the demonstration zone manager, as a collaborative partner.

With devices in the water between 1 and 12 months, the Marine Energy Testing Area is a steppingstone towards grid connection and ultimately arrays. Interviewees viewed it as an opportunity to “test not only devices, but components and techniques. Why not get everything right before you leave the port?" (SC5). Furthermore, interviewees credited the Marine Energy Testing Area as supporting supply chain skills development as this would provide early opportunities to engage with these new innovative technologies. In developing the Marine Energy Testing Area alongside the demonstration zones, the evidence suggests that it is part of a wider aim to become a focal point for the industry.

Embedding goals become further apparent when the Marine Energy Testing Area is posited by Wave Hub Ltd as a flexible space for developers “to undertake their initial testing before deploying at scale in the demonstration zone.” This again shows a strong embedding influence where there is the aim of locking the developers into the region from conception stage onwards. It can be summarised that this is distinctly viewed as an opportunity for the region, where MEW further “provides a single point of access for marine energy developers interested in Wales” (SC5).

The evidence suggests that the overall outlook of Pembrokeshire as a ME development zone is particularly positive, with much local enthusiasm around progress. It can be suggested that these embedding developments can be affiliated with the momentum that was generated by MEP and followed by actions of MEW. Whilst these developments have an impact across Wales, it would seem that the introduction of initiatives such as the Marine Energy Testing Area were driven by MEW in anticipation of benefits being gained by the Pembrokeshire (NUTS3) region.

7.4.3 Anglesey

7.4.3.1 Overview

Anglesey has fewer key actors than Pembrokeshire, consisting of Anglesey County Council that are responsible for the ‘Anglesey Energy Island’ Enterprise Zone and Morlais, the demonstration zone manager. Together these are the main actors through which prospective local embedding of the MEI is pursued, much like Pembrokeshire, the number of actors in the region aligns with the theorisation of a low number of actors in a less-developed region. Alongside these organisations, and much like the South Wales City Deals, the North Wales Economic Ambition Board was formed in 2017 and is a partnership between six county councils, businesses, colleges and universities as part of the North Wales Growth Deal. The proposal is to invest £383.4m into the North Wales economy to enable £1.3bn growth, with a return of £3.40 for every pound spent and the creation of 5,000 jobs (North Wales Ambition Board, no date).

The Enterprise Zone focuses on 'low carbon' which aligns with the existing regional industry focus on nuclear, with the Wylfa nuclear power station operating from 1972 to 2015 (Shrestha, 2019). The Wylfa Power station provided many jobs with high wages, the average weekly salary in April 2015 on Anglesey was £450 per week, this is higher than Cardiff at £403 and significantly higher than Pembrokeshire at £328 (ONS, 2015). This might give some insight into the motivations behind the significant support for nuclear across Wales and particularly in the Anglesey region.

Whilst conducting fieldwork (2016 – 2019), a new nuclear station was planned, yet the negotiations stalled in early 2019. Following the announcement that negotiations with Hitachi (the one-time lead investor) had stalled, the Economy Secretary for Wales pledged more support for the North Wales Economic Ambition Board. The way in which the new Wylfa nuclear project (Wylfa Newydd) continues to be pursued by the WG could be considered evidence of the uncritical attitude adopted in political circles in Wales towards nuclear. Indeed, the growing evidence in this thesis is that the support of nuclear has adverse effects on RE expansion.

A unique aspect of Anglesey is the prioritisation of the Welsh language. Inward investors must explicitly commit to language development within their operations. This policy came in response to language decline because "youngsters are moving away and not coming back because there are no job opportunities" (GV3). This also puts additional pressure on job creation. GV3 stated that the Welsh Language commitment was "given the same status as environmental impacts, which are so heavily regulated they're 'no brainers'".

It could be argued that in the framework of language being commensurate with the environment, nuclear will remain the favoured technology, given the frequency with which it is represented as ‘low carbon’. In the context of a region that desires many jobs, this creates a difficult context for smaller, more novel sectors like ME. It is within this context the work of Anglesey County Council’s ‘Energy Island’ and the demonstration zone development will be considered.

7.4.3.1 Regional decline and MEI support

The ‘Anglesey Energy Island’ programme was established in 2010 by Anglesey County Council as a strategic response to the closure of big employers in the region (NUTS3). These employers include an aluminium smelting plant and an awareness that the energy generation lifespan of the Wylfa nuclear plant was coming to an end. These businesses collectively took on twenty to forty apprentices per year.

> “The council put a line in the sand that if the economy was to thrive then there was a need to attract new investment and businesses, not relying on existing business and start-ups” (GV3).

‘Anglesey Energy Island’ sits within the wider Anglesey County Council so that there is a whole-council response rather than solely planning or economic development. The programme has a forum that brings developers together with statutory consultees and meets on a quarterly basis. Performance is reported through quarterly management systems within the county council to ensure strategic alignment (GV3).

In 2017, the Anglesey County Council interviewee highlighted the large number of underemployed residents, particularly steel fabricators. The timeframe between the smelting plant closing and no new industry opening had meant that the region had witnessed a “dilution of people’s economic power and ability" (GV3). Therefore, attracting a new nuclear operator to Wylfa was the main thrust of the Energy Island programme, complemented by “some marine energy components” (GV3). The interviewee highlighted that the underpinning of ‘Anglesey Energy Island’ was economic development, not energy.

The interviews were conducted whilst there was still the prospect of Wylfa Newydd and the MEI interviewees across Wales did not hold ‘Anglesey Energy Island’ in great esteem. There was a range of comments with respect to the unbalanced privileging of the nuclear industry due to the potential jobs to be gained. There were many negative comments around a lack of social capital and that it is "unclear who's in the driving seat in Anglesey". This raises questions as to the extent to which embedding is impaired by the perception of regional actors by technology actors, an aspect that could be posited to influence the quality and structure of relationships. A developer previously based in the region stated that the ‘Anglesey Energy Island’ programme was not interested in their technology despite the high level of public exposure brought to the region as a result. It could be contended that the Energy Island programme acts, effectively, as an intermediary geared towards the incumbent technology.

This seemingly negative relationship between ‘Anglesey Energy Island’ and ME existed before the announcement of the failed negotiations with Hitachi for Wylfa Newydd. Where the jobs that come with a ME device are “extremely important”, these jobs "are not of a scale that’s needed on this Island with the critical mass needed to stimulate economic development" (GV3). However, with nuclear development stalled and the progression of the demonstration zones, ME now presents the more immediate possibility for regional development, however limited. With the low social capital and trust between Anglesey County Council and the MEI, what then is the future potential for Anglesey County Council to influence the development of the MEI?

Whilst interviewing a representative of ‘Anglesey Energy Island’, it became apparent that there was an opinion that many of the ME developers were in Wales solely due to the convergence funding available. When asked about TD3 locating an office in a town centre to increase engagement with the public (noting all employees are from the region), the response alluded to ERDF funding and the need to invest “somewhere in Wales to actually claim it”. Whilst this evidence is attributable to one individual it raises an important issue with respect to embedding a technology. Thus far, the ERDF funding has been established as a useful tool in attracting developers to a region, and actors in Pembrokeshire are capitalising on this to draw down further benefits. However, in Anglesey it is apparent that these first-step activities are not treated as the same opportunity highlighting a divergence in regional ethos.

Members of the ‘Anglesey Energy Island’ initiative previously attended MEP meetings and annual conferences, but “it was questioned how much this was of value” and therefore the programme “keeps an eye” on developments rather than having an active involvement. The MEP representative highlighted that initially they sought to establish how MEP and ‘Anglesey Energy Island’ could work together, beginning to "put a bid together to have a marine energy officer based up in Anglesey". When Morlais became the third-party manager of the demonstration zone these funds of around £40k were diverted to support Morlais. This evidence highlights potential loss of trust between actors, where MEP had undertaken activities and resources were then directed elsewhere. Arguably, the knowledge developed by MEP could accelerate Morlais’ pathway to effective engagement with the MEI.

Further evidence of the absence of activities to foster social capital in Anglesey includes the Orkney consultancy (that now has offices in Wales) noting that for a tender advertised in North Wales a collaborative bid with other organisations engaged in the MEIW was submitted. However, a large international consultancy firm was selected by the WG and Morlais. This was seen as discouraging and counter to what the political ethos is stated to be in Wales of encouraging local engagement.

As a result of previous experiences in Orkney, the consultancy plans to undertake activities to contact and engage with the winning consultancy. Previously on Orkney, contracts awarded to ‘mainland’ companies with lower costs were found to “not have any of the local knowledge, so will possibly have some difficulties picking up the pieces" of how the region works. In this instance there were knowledge gaps that the Orkney consultancy was be able to fill. The interviewee also highlighted how hiring large consultancy firms in Anglesey has potential to not be well viewed by the region as "local people just see these companies come in, make money and then go away again and don’t put into local economy."

This shows an interesting duality in Wales, where the WG view MEW as a significant actor within the MEI, and ‘Anglesey Energy Island’ does not engage extensively with the industry, highlighting the role of actors in both the innovation and transition process. The regional ethos in Anglesey likely aligns with the regional narrative that only a nuclear plant would have the critical mass to sustain employment and the supply chain. Austerity and low staffing potentially restrict the ability of this local government actor to engage with a range of innovative technologies. Further in this light, the ‘Anglesey Energy Island’ interviewee considered that Anglesey County Council is “not big enough” to engage with innovation or supply chain support. These activities are therefore escalated to the North Wales Economic Ambition Board or reliant on the WG approach.

It could be advanced that ME in Anglesey is entwined with the overall tendency of government actors in Wales to compare technologies on prospective employment grounds with limited consideration of the opportunities presented to the region. One of these opportunities is the tidal energy demonstration zone which will now be elaborated.

7.4.3.2 Focus on Demonstration Zones

The main embedding focus in North Wales is that of the demonstration zone, which was initiated and sited by the CE. The site was later moved north due to research undertaken by SEACAMS1 as it was found that the whole south of the originally proposed area “had giant sand waves with the tides...so anything on the seabed would have been swamped quickly”. This demonstrates how collaborative working between actors within the MEI can contribute to the development of the industry. This is important to the embedding process as overall success for those developers that engage with the demonstration zone will bring positive attention to the region and its capabilities.

Morlais possess the certificate to manage the seabed; the organisation acts as an intermediary between Anglesey County Council and the CE. The demonstration zone has also meant that ME developers contact Morlais rather than approach ‘Anglesey Energy Island’. GV3 considered this a positive move as the council could "step away and do other things", putting Morlais in a pivotal role for the development of ME in Anglesey. Menter Mon, the parent organisation of Morlais, has a local focus on Anglesey and Welsh language capacities - features that several interviewees believed to be part of the reason for their selection.

Anglesey County Council, a statutory consultee responsible for the planning permission for the subsea cable coming ashore for the demonstration zones, must be cautious in its relationship with Morlais (GV3). This raises questions around the ability to work collaboratively within a region with a low number of institutions and the need to be wary of conflicts of interest. It will also be important for Anglesey County Council to have knowledge of the activities that are taking place and whether training support is needed by the local supply chain (GV3). In this respect Anglesey County Council might interact with Morlais and the developers in both a statutory and regional development perspective.

As a result of this, Morlais is a member of the ‘Anglesey Energy Island’ forum as a 'developer', with early dialogue thought by GV3 to de-risk the demonstration zone development process. Commercially, Anglesey County Council is seeking to understand what measures can be put in place whilst the devices are being piloted. The testing that will take place within the demonstration zones "determines whether there is a product that can be exported” (GV3). This product may ultimately lead to “territorial economic development, but this is very far down the road" (GV3). In this respect there seems to be a tension between the level of support 'Anglesey Energy Island' provides to the MEI and the support Anglesey County Council provides to the demonstration zones which support the MEI.

Morlais is explicit about embedding the "maximum benefit for the economy of Anglesey" and servicing needs "should be accessed locally whenever possible and practical" (Morlais, 2020). The Morlais website also provides a list of the types of services and skills that can be found locally. Morlais' organisational ethos could be commented as emulating the agenda of 'Anglesey Energy Island'. It is striking that none of the demonstration zone berth holders have previously operated within Wales, positioning the demonstration zone as a significant step towards attracting technologies in the region. In the absence of other supporting measures, it is uncertain whether these technologies will come to be embedded in the region for a longer timeframe than demonstration zone operation.

More broadly within the region, developers that are not part of the demonstration zone consider the development to be positive progress. TD3 predicted local supply chain improvement and the opportunities for locals would act "as the catalyst for the emergence of SMEs that are in/directly related." TD3 cited that the proximity to the grid had influenced their location in the region; there were other similar marine resources suitable for the technology, but Anglesey had the "best grid access opportunity in the world". This grid capacity is a legacy of the nuclear industry and the limited additional cabling required was seen as advantageous by TD3 as cabling costs are significant. Further, within the region "there is poor community outlook on overland pylons, so cables would need to buried and this is an even more expensive process" (TD3). This suggests that for those developers that are beyond the requirement of the demonstration zone the initiative may further facilitate embedding. The next discussion section will consider the different outcomes that have been achieved as a result of regional strategies.

7.5 Discussion

This chapter establishes that the two scales of regional activity possess different narratives. However, the need for modular marine technology to compete with larger technologies is ever present. Nuclear is favoured across Wales and Anglesey, and the Swansea Bay Tidal Lagoon across Wales and Pembrokeshire. This suggests that the WG and regional development agencies have some work to signal support of modular technology developers to provide the degree of certainty required for a successful industry. At the same time, the MEI has some work to do to gain the level of political support it desires. This aligns with the MLP mechanisms of simultaneous push and pull, as opposed to the TIS notion that knowledge flows through the innovation system without hierarchy.

This said, there have been key developments undertaken to help embed the industry in Wales. Summarised in Table 7.1 these events can be considered outcomes of the processes described within this chapter. Within Table 7.1 those events in bold are events that could be considered embedding failures. These embedding failures relate to developers either trialling technology at other locations or considering other markets for their technology. These failures can be classed as regional losses, as were the organisations to embed elsewhere following local support, the long-term benefits of the monies invested would also leave the region.

Year	Month	Outcome
2015	Dec	TD4 installs off Pembrokeshire Coast
2016	July	Opening of Marine Centre Wales, Bangor
	Aug	Pembrokeshire's new marine hub opens
	Oct	8 berths signed up at Anglesey Demonstration Zone
	Nov	Marine Energy Wales launched
2017	July	Pembrokeshire Coastal Forum secures funding for supply chain project
	Aug	Coastal communities funding for: Mainstay Hoist, NOVA expansion in Wales, and Marine Energy Testing Area
2018	July	**TD5 installs at Fabtest, Cornwall**
	July	Scotland and Cornwall to support development of Marine Energy Testing Area
2019	Feb	**TD3 explored options in the Caribbean**
	April	**Bombora is selected by Enzen for Lanzarote** Energy consenting powers further devolved to WG

Table 7.1. Technology Embedding outcomes in Wales.

Source: Author's own.

The interview evidence has outlined how a number of these leakages were foreseeable. TD5 outlined at the time of interview in 2016 that it was likely that the technology would have sea trials elsewhere as the demonstration zones in Wales would not be developed quickly enough. This highlights a failure on the part of the WG as demonstration zones were agreed in 2014 and bridging measures were not implemented. Developers were aware that the demonstration zones would take some time to implement, particularly in Pembrokeshire with plans to incorporate "lessons learnt down in Wavehub Cornwall, which is good but will take a long time" (TD5). This highlights how, in relation to transition and technology embedding, temporal aspects can play a critical role in the success or failure of a technology within a region.

A further regional loss of note is TD3 exploring options in the Caribbean when the developer is based in Anglesey and has received a high level of ERDF funding. TD3 technology is developed and tested in situ in Anglesey, meaning that many aspects of the technology are embedded within the region. These explorations present a risk of ERDF funding benefit loss and questions arise whether this is linked to TD3's experience in Anglesey or the nature of this type of technology. Whilst it is not possible to establish whether this is the case, it does highlight that developers have a high level of mobility which places greater significance on embedding operations in the region. This evidence increasingly supports the hypothesis that embedding the technology in the region will be important for both innovation and transition processes. Further, it highlights the need for actors to be motivated to engage with these processes.

In this respect, if ME is considered as an assemblage (De Landa, 2006), it is possible to better conceptualise the proximity of functions to the natural resource, and what aspects might be embedded or more footloose. The evidence suggests that the most local feature of the innovation system to the marine resource are supply chain companies that contribute to the operation and maintenance of the technology. It is notable however, that this is the final stage of the innovation process, but based on the evidence, has some of the greatest potential for long-term regional benefits. However, in terms of governmental actions to support industry development, the evidence establishes that there are limited activities to support supply chain upskilling that could ensure the success of the MEIW.

Interview and scoping conversations with fleet vessel companies highlight that the manufacture and deployment of devices can be completed by organisations that are not in the region. This comes as a result of the modularity of the technology and the UK's island geography where vessels can easily travel from Scotland or elsewhere. In many respects this could be a positive aspect for less-developed regions as vessels are expensive and for

ME have specialist requirements. A design feature of TD5 was the device's ability to be towed by non-specialist vessels. This ease of mobility is common with RETs, with the ability to deliver assembled devices to an area. Regional attitudes to these technologies may therefore differ, comparing construction of large-scale power stations to device manufacture and servicing. However, it should be noted for a long-term regional development outcome many of the power station construction jobs are temporary and serviced by individuals from outside of the region (TD3).

It has been established that the developer need not be local to the resource continually, with the ability to engage intermittently. When the TIS is instigated by the entrepreneur (Carlsson and Stanckiewicz, 1991), where that entrepreneur or developer is based is important in defining the geography of the innovation system. Where TIS literature shows that cluster activities can be based where the innovation or manufacture takes place, it could be suggested that a third location is available to RETs - where the technology is operated due to the requirement for 'local' employees to engage in this continuous maintenance process. The evidence in Wales suggests that many developers in ME locate near to the natural resource but it is not without challenges to establish and maintain an industry.

The footloose nature of the developer suggests the need to create objects of permanence to attract, embed, and draw-down long-term benefit to the region. The evidence suggests that the most easily embedded features of the TIS are the physical and financial attributes, where grid structure and grants are evidence of this embedding in Wales. However, it is notable that the grid infrastructure is a legacy of the hydrocarbon industry and the supplemental infrastructure of the demonstration zones is a CE initiative rather than that of the WG. Again, this highlights the endogenous-exogenous tension of actors who seek to drive the development of the industry. WEFO guidelines seek to unlock some benefit for the regional supply chain, however, these criteria are set by the EU.

It could be argued that there is missing activity at the Wales NUTS1 scale to embed developers, drawing on clustering principles steps ought to be taken to produce a critical mass to the industry. The evidence highlights the enterprise zones which offer favourable conditions, but this is linked to the economic development of a region rather than the embedding of entrepreneurs. Likewise, The Swansea Bay City Deal provides additional support to Pembrokeshire, but the detail of the initiative was driven by the applicants rather than the WG. This matters as it is further evidence of the emerging narrative of intermediaries addressing structural weaknesses in the MEIW.

Considering the assemblage of ME in Wales raises questions as to whether the evidence makes it possible to draw conclusions on how best to embed the ME industry. Whilst not fully within the scope of the research, there are preliminary findings. The most striking element of the subregion analysis is the divergent outcomes between Anglesey and Pembrokeshire, suggesting aspects of the activities undertaken in each region that contribute to or detract from embedding.

Whilst acknowledging that MEP was set up with the MEI in mind, a far higher level of technology embedding has been achieved in Pembrokeshire. This is due to many factors but can best be attributed to a better understanding of the needs of the nascent industry. Whilst economic development is the driving force behind the Pembrokeshire (and wider South Wales region) initiatives, 'jobs and growth' are not foremost in the narrative with a wider range of support for technology development and embedding. In contrast, Anglesey holds on to the possibility of new nuclear and activities in the region focus on supporting the development of this technology. This shows the intersection between spaces of innovation and transition, where prescriptive demands placed on innovation outcomes stalls the progression of a pre-commercialisation industry through the niche and delays sustainability transition.

Where MEP is an intermediary for the MEIW, the evidence suggests that 'Anglesey Energy Island' is an intermediary for nuclear which is an existing technology trajectory in the region. Arguably this incumbent technology is being repackaged as ‘low carbon’, but the pursuit of nuclear and the relative marginalisation of ME potential shows a high level of regional path dependency. This further highlights the tension between developing innovation that can then contribute to sustainability transition, where the experimentation phase of the technology in the niches faces further pre-commercialisation hurdles as already dominant technologies are positioned as challengers.

The literature establishes the importance of social capital and the benefit of networks of relationships in a region, with hypothesises that actors will be particularly important regional characteristics. MEP, as a result of many years of operation and pro-active engagement with actors from across the industry, has fostered both local and regional knowledge networks. Acknowledging the infancy of Morlais as an organisation, ‘Anglesey Energy Island’ on the other hand has done little to foster positive relationships within the locality. Where it was posited that actors would drive the transition process, the evidence shows this is influenced greatly by their agency.

Actors in Pembrokeshire have pursued a number of durable features in the region that have attracted and will potentially retain developers. The Australian technology developer is an example where the organisation was attracted to the region initially by ERDF funding, but headquartered in Pembrokeshire due to the additional regional benefits, including the Marine Energy Hub. This aligns with the cluster literature where the more actors are attracted to co-locate there is increased chance of new-to-the-market or region technology being created (Shearmur and Doloreux, 2016; Grillitsch and Nilsson, 2015).

Pembrokeshire offers a range of ‘services’ that are available to technology developers as they progress along the technology readiness level, making it more likely that the developer remains in the region once operating arrays. The ability to access knowledge from multiple experienced sources such as Wave Hub Ltd and other consultancies will be beneficial for developers in Pembrokeshire. This evidence suggests that should Anglesey wish to pursue a higher degree of embedding it would be necessary for Morlais to focus on developing these regional attributes alongside the demonstration zones, all supported by a high degree of social capital.

This said, the fieldwork highlighted the different capacities of MEP and Morlais as organisations of a similar size. An interviewee highlighted how they had encountered many difficulties in connecting with Morlais despite being a representative of an influential organisation within the MEIW. The interviewee stated that "we wanted to do our usual softly-softly approach, but a few months have passed, and I maybe need to be a bit 'pushier' now"[2]. This suggests that the mere presence of an intermediary organisation is not sufficient and suggests the skills required to be effective in this role. Furthermore, this evidence pertains to the relational view of social capital where trust is established over an extended timeframe (Nahapiet and Ghoshal, 1998).

In summary, the evidence suggests that the extent to which actors may mobilise to embed a new technology within a region relates strongly to the motivation of the region to recognise traditional energy industries are on the decline and there is a need to create a new path. In Pembrokeshire, there is a strong bottom-up approach to embedding ME in the region and it can be argued that these actors are seeking to create a new path, replacing hydrocarbons. In seeking to create this new path, with knowledge of the region's position as a less-developed region, it could be said that actors such as the MEP seek to mobilise the limited regional resources to their best advantage. Indeed, the strategies adopted including building a network are things that can be achieved with limited resources. On the other hand, Anglesey exhibits a strong degree of path dependency (around nuclear) and limited localised activities to promote embedding. It could be

2 The author experienced a similar outcome where attempts to arrange an interview all failed.

suggested that the narrative of embedding in Anglesey is most similar to the strategies adopted by the WG.

Arguably, it is not possible to conclude that a state of ‘success’ has yet been achieved in embedding the MEI in Wales, but when comparing the regions it would seem that Pembrokeshire operates with more cognition of the power of social capital, knowledge sharing, and cluster activities. This embedding both supports the development of innovative ME technology and the drawing down of regional economic development benefits. The evidence also suggests a range of emerging themes on the nature of relationships, role of intermediaries, and establishing whether transition is taking place. These themes will be explored in greater detail in the next chapter encapsulating the causal power of market creation, innovation support, and technology embedding mechanisms.

Chapter 8 Evaluation of mechanisms for transition

8.1 Introduction

This thesis seeks to explain the social factors that influence long-term technological changes, in particular, how the characteristics of a region influence sustainability technology transition. The way in which the economic development benefits of innovation can be drawn down into the region is also considered. The preceding analysis chapters highlight a range of mechanisms that were deployed to contribute to transition in the marine energy industry in Wales (MEIW), the purpose of this chapter is to synthesise key themes and reflect on literature.

The evidence highlights how actors within less-developed regions can attach multiple goals to technology change, in particular seeking to address regional development issues such as the need to create employment opportunities. This establishes that regional characteristics, including the type of actor present, will impact sustainability transition. A less-developed region will have two main trajectories to manage: innovation support and enabling regional growth. Key themes that emerge are the impact of absorptive capacity, how learning from failure can contribute to transition, the challenges actors face in developing in advance of key institutional support and leadership, and how multiple actors shape the demands on the industry.

The chapter will begin with an exploration of the Q method results, which are designed to establish the groupings of opinions of a diverse range of actors. This will be followed by an analysis of how spatial aspects of the region of Wales have influenced technology trajectories, seeking to elaborate whether a transition is indeed taking place. Following this, consideration will be given to the relationships and knowledge sharing evidenced in the MEIW. Finally, the role of actors in enabling transition will be evaluated.

8.2 Q method – emerging marine energy industry narratives

8.2.1 'Analytical Narrative'

The evidence detailed in the market creation, innovation support, and technology embedding investigation generated a wide range of observations that formed the first stage of analysis undertaken by the researcher, the 'analytical narrative'. This analysis informed the Q Methodology statements and these observations were filtered into twenty-four statements that are found in Appendix C. The Q Method statement ranking was then used to corroborate the importance of the narratives that emerged from the interviews and secondary data analysis. In this way it is possible to establish the features that are important to participants and the industry more generally, providing further insight into the mechanisms that support transition, and their relative explanatory power.

The 'analytical narrative' is summarised here to establish the evidence that emerges from the first stage of data collection, before comparing with the narrative that emerged from the Q method. The evidence thus far has established that Marine Energy Pembrokeshire (MEP) and Marine Energy Wales (MEW) have been very influential in the industry development process. These actors have helped navigate institutional deficiencies and promote both knowledge network building and institutional entrepreneurship activities. These activities include industry-wide meetings that facilitate networking and establishing knowledge sharing channels with other regions such as Scotland.

The evidence suggests that actors have potential to enhance absorptive capacity and minimise transaction costs through utilising actors such as MEP to connect with others. Actors can use this network to access desired information and undertake collaboration to gain new knowledge. In this context, the interview data outlined a predisposition to working with businesses that are culturally similar. Failure is viewed as a source of knowledge, with some developers seeking to recruit employees from disbanded technology developers. Within MEW events, lessons learnt by the supply chain have been shared and this could be considered an important source of knowledge. Many interviewees spoke of their work in other industries such as wind, oil, and gas - outlining the potential of knowledge flow between industries.

The evidence shows that, much like with other innovative technology, a lack of funding and financial support will hinder development. In Wales, public sector financial support has come from ERDF monies whose funding rules were found to be restrictive by developers. These restrictions include the need to source a majority of supply chain needs in Wales, with some interviewees highlighting that this was not always possible. Some interviewees also identified skills shortages in parts of the supply chain in Wales - a risk for the continued development of the industry.

Institutionally, Chapter 5 (market creation mechanisms) found evidence of gaps in WG policy support for the MEIW, and Chapter 7 (technology embedding mechanisms) highlights that there are limited efforts by local government or other statutory agents to facilitate network development. Despite a high degree of investment within university-based marine resource research, the evidence found weaknesses in the wider network of support for transition from the universities and other actors highlighted in Chapter 6 (innovation support mechanisms). In the future, the development of demonstration zones is likely to influence industry development in Wales, further contributing to industry transition.

8.2.2 Q factor Results

The preceding ‘analytical narrative’ can be viewed as a first stage analysis that establishes the main narrative that emerged from the interview material and other data gathered in the first part of the research. The sorting of the twenty-four Q statements then make it possible to encapsulate the main groupings of opinion related to the wider activities and requirements of the MEIW.

The Q Methodology results show that there are four principal factors (or clusters of people) with similar opinions that emerge from this next stage of analysis. These factors have an Eigenvalue over 1, meaning that this explains the opinion of more than one person. The factor with the highest Eigenvalue is the most dominant cluster of opinion of the respondents. These four factors are summarised in Table 8.1, showing the ranking of the statements and the transition mechanism category to which the statement belongs.

Those people who belong to one factor have something in common that differentiates them from the clusters of people within another factor. Factor 1 explains 32% in the variance of opinion clusters, with the following three clusters explaining 15%, 13%, and 12% respectively - to a total of 72% explained variance.

Q sort rank	Factor 1	Factor 2	Factor 3	Factor 4
3	9	15	9	15
2	14	20	20	10
2	20	7	7	21
2	18	22	10	7
1	10	9	16	14
1	15	5	18	1
1	11	10	22	5
1	7	11	8	18
1	16	1	12	20
0	6	8	2	9
0	19	14	3	16
0	13	4	11	11
0	5	21	6	2
0	2	16	14	17
0	8	17	1	8
-1	12	6	17	23
-1	4	19	23	24
-1	22	12	24	3
-1	17	3	15	13
-1	1	18	19	4
-2	23	24	21	19
-2	24	23	13	6
-2	3	13	5	22
-3	21	2	4	12
Eigenvalue/ Explained variance	2.9/ 32%	1.4/ 15%	1.2/ 13%	1/12%
Key:	Embed	Pull	Push	

Table 8.1. Q Factor Analysis summary table.

Source: Author's Own.

8.2.2.1 Factor 1 'Embedding Group'

Factor 1, referred to as the 'embedding group', most strongly identifies with the support of embedding activities in order to progress the MEIW. The group consider institutional support to be lacking and is neutral about the need to share culture and location with other businesses. This group is the dominant narrative explaining the opinions of the greatest number of participants. This group also has the clearest grouping of opinions: mostly agreeing with embedding statements such as 'MEP/MEW being influential for industry development' and 'the importance of industry-wide meetings'; some agreement with innovation support statements such as 'learning from failure' and 'a network of contacts allows easy access to information'; and generally disagreeing with market creation statements such as 'there is a skills shortage in Wales' and 'EU funding guidelines are restrictive'. However, due to the nature of Q method statements and the preservation of original source tone, disagreement with a statement is not necessarily a negative outcome. This shows the power of Q method to collate potentially polarised opinions (Ellis et al., 2007).

Importantly, the 'embedding group' is of the opinion that EU funding guidelines are not 'restrictive', that there are not perceived problems with the 'supply chain' or a 'skills shortage'. This tempers some of the initial findings, perhaps highlighting that these issues are most acutely perceived by certain groups of actors. At the same time, the high regard for embedding statements signifies a general opinion that embedding will be important to the industry future in Wales.

The individuals within the 'embedding group' that had the highest factor-loading (or level of agreement with the discourse) could be considered high-profile actors engaged with promoting ME in Wales. It is likely that these actors would prioritise region-based proposals to strengthen the industry. Interestingly, these individuals and the organisations they represent are also strongly networked with one another. This suggests that the industry is being led by a group of organisations with a shared vision - an element considered integral to sustainability transition (Inkpen and Tsang, 2005). One individual, who previously was part of a disbanded technology developer did not align with the discourse. This individual is, however, one of the main proponents of Factor 2.

Within Factor 1, the dominant discourse, it is significant that ‘MEP& MEW’ and the ‘industry wide meetings’ organised are the two most important statements. This is followed by the idea that a ‘lack of funding’ curtails the industry and that ‘demonstration zones will be influential’. Factor 1 aligns with some of the main theorising of this thesis – that in a less-developed region a low number of actors can shape the transition and industry development, with social capital as one of the main vehicles for doing so. This does not negate the impact of other aspects such as funding difficulties but allows the opportunity for change.

Following this high level of agreement, there is also a positive alignment with many of the statements related to the industry. These statements concern the ability to access knowledge through innovation support mechanisms such as ‘collaboration’; embedding factors such as ‘failure’, ‘networks of contacts’, ‘learning from other regions’; and the ‘ability to tap into ready prepared information’ that could be provided by market creation actors. The ‘embedding group’ are neutral in their opinion about the impact of ‘actors that are co-located’ or ‘businesses that share a similar ethos’. Furthermore, the group identified neutrally with the impact of ‘universities on their business’ and ‘keeping knowledge within the industry by hiring employees from failed companies’.

The ‘embedding group’ considered that WG policy was not sufficiently ‘supportive’, reflecting the findings of Chapter 5 (market creation) that policy and institutions have low efficacy at a local level. Supplementary commentary outlined that the primary problem was an absence of financial capacity to enact industry support. The group did not identify a ‘skills shortage’ across the industry. However, Factor 4 and other commentary shows that it is perceived to exist by some respondents, suggesting issues with discrete supply chain tasks rather than an overall skills shortage.

Alongside this, it must be remembered that respondents will have different goals from the progression of the MEIW – some will value driving forward technology innovation and others will seek economic benefit for Wales. The analysis thus far has shown that these agendas are not fully compatible, and as a result there will be divergence in some of the Q Factors.

However, the important element of Factor 1 is that with a high Eigenvalue and explanation of variance, it could be suggested that there is a narrative that might mediate the action required to produce a workable fix between innovation support and economic benefit. The 'embedding group' would suggest that it is important to pursue embedding activities, but also necessary to supplement these activities with sufficient access to funding and financial opportunities. However, it can be suggested from the empirical research that this could be achieved through grant funding or by removing barriers to private investment, thereby bolstering market creation. A further mechanism for market creation identified by the 'embedding group' would be sufficient policy support from the WG and the preparation of geographical and environmental data. These aspects could be surmised to be within the capacity of the WG and the universities in Wales.

8.2.2.2 Factor 2 'Collaboration Group'

The Factor 2 'collaboration group' is most positive about 'collaboration to gain new knowledge' and the policy support provided in Wales. The group was, however, neutral about local knowledge sharing. The 'collaboration group' most disagreed with the proposal that a University played an 'important part' in their operations. Much like other factors, a 'lack of funding' was identified as impeding the industry, but the guidelines associated with EU funding were not 'restrictive'. The 'collaboration group' was the only one to credit WG energy policy as 'sufficiently supportive'. The group also identified 'failure as a source of learning' with additional commentary outlining the proviso that this could be accessed easily through consultancy work. Failing this, commentary also outlined that “you can sometimes get lucky through networking or Marine Energy Wales facilitation”.

The collaboration group also identified embedding elements such as the ‘MEP/MEW’ and ‘learning about the experience of other regions’ as supportive to industry development. However, whilst ‘locating in an area with other supply chain’ allows for more effective working, ‘companies in the same region’ were not important to business processes. One respondent highlighted how communication technologies made proximity less vital, which has implications around the growing prevalence of notions of relational proximity. When coupled with the prioritising of collaboration, a desire to pursue colocation to benefit from the supply chain rather than knowledge spillover might be highlighted. Indeed, a commentator outlined that clustering would be effective in raising the profile of ME and building supply chain experience more than with the aim of supporting innovation per se.

Market creation elements such as ‘readily available data’ and ‘experience in other industries’ were supported by the group. Opinions were neutral on ‘skills shortage’, ‘networks of contacts’, and ‘non-statutory bodies’ influencing industry development in Wales. This group, however, least favoured the embedding elements rating four of eight as neutral-negative, and this was the only group that did not agree that the ‘demonstration zones would be influential’. Overall, it could be argued that this is the counter-narrative to Factor 1 which values the embedding of activities within a region, where Factor 2 values collaboration irrespective of location. This has implications for clustering, how it is perceived, and the extent to which embedding might play a role in industry transition. It seems likely that this group are more interested in the innovation than the regional development aspects of the MEIW.

8.2.2.3 Factor 3 ‘Knowledge group’

The Factor 3 ‘Knowledge group’ was most positive about readily available information and networks, and not driven by activities such as ‘balancing business demands with research’ or ‘undertaking collaboration’. Much like Factor 1, the ‘knowledge group’ viewed ‘MEP and

MEW' as the most influential element for industry development in Wales. The 'knowledge group' also aligned with Factor 1 and 2 that a 'lack of funding' was an impediment to industry development. This group highly rated 'learning from failed companies' but considered 'locating in an area with other ME companies' not an effective work strategy. 'Business culture' and 'collaboration' were not important, and the group considered that there was no 'skills shortage' in Wales.

Interestingly, despite rating MEP as 'most influential', the group were neutral about 'learning from other regions', 'keeping knowledge in the industry', and gaining 'networks of contacts'. This could perhaps be an outcome of the diverse work that MEP and MEW undertake, with Factor 3 not valuing the knowledge networking activities but other business-networking and institutional work. As this factor does explain a much smaller extent of the variance, it is principally influenced by two respondents, who could be considered outside of the core network of the MEIW highlighted in Factor 1. This factor did have three respondents in disagreement, confirming that this is a more outlying and contested opinion.

8.2.2.4 Factor 4 'Skills Group'

The Factor 4 'skills group' identifies the potential for a skills shortage in Wales and is the one group that is neutral about the activities of MEP and MEW. The 'skills group' highly valued 'collaboration' and the ability to 'tap into ready-prepared data' and 'learning from failure'. At the same time, the group did not agree that 'sharing lessons learnt' had affected their organisation and were the most negative group with regards to the quality of 'Welsh Government policy support'. The group was neutral about the impact of 'MEP and MEW', 'networks of contacts' and 'learning from other regions' - these factors supporting one another in an opinion frame.

The group was supportive of embedding elements such as 'industry-wide meetings', 'co-location' and 'demonstration zones'. This perhaps shows an appreciation of embedding efforts where skills availability needs to be better addressed. The main contributors to this group were supply chain actors, yet a developer and supply chain actor disagreed significantly with the factor. This perhaps suggests that this skills gap is within specific sectors of the supply chain.

8.2.3 Q method conclusions

What does emerge from these four factors is that two statements have the highest level of agreement: that 'MEP/MEW are influential to industry development' in Wales and that organisations 'undertake collaboration to gain knowledge and strengthen relationships'. One respondent highlighted how they:

> "really can't see how so many important stakeholders (e.g., Welsh Government, WEFO, Politicians, Ports, Suppliers, City Deal etc) would have provided backing to make the industry grow without the centralised voice of MEW".

A finding for the first stage analysis, further supported by the Q method, is that there is great potential for the WG to further promote market creation and technology embedding activities through the provision of additional readily available data. This to some extent is being supported by the activities of SEACAMS but Factors 1, 3, 4 are neutral and Factor 2 is negative about the contribution of universities to their activities. Several comments centred on how the universities needed to be more "hands on"; it can be concluded that whilst supporting the wider development of the industry, the Universities do not currently support day-to-day operations.

One respondent outlined that academics can be good centres of knowledge as "they don't tend to move about too much and have been in office longer than most technology developers". This introduces an interesting aspect of knowledge longevity, highlighted in the interviews as an issue when technology developers disband, and employees leave Wales. Coupled with interview data, it could be suggested that the influence of universities in Wales would be improved with greater collaboration with developers. Further, the level of gatekeeping of data created within these projects curtails dissemination and impact.

The evolutionary nature of the industry is best summarised by the strong thinking that 'failure is an opportunity for learning', but overall, there is a neutral outlook to 'employing the individuals from those failed organisations to lock in knowledge'. However, the interviews suggest that recruiting employees of failed organisations is more important to developers than perhaps the overall industry. More generally, a skills shortage is not identified in Wales, however, this statement is limited by the non-specifying of industry-type and those interviewees that highlighted the issue were within the steel industry. This therefore suggests that it is an issue that may not be known by the wider MEI or that some respondents are less concerned with Wales being short of skills as they can be sourced from elsewhere. This is supported by the ongoing decline of the steel industry trajectory outlined in Chapter 7.

It was generally considered possible to source supply chain needs in Wales which correlates with the finding that ERDF funding guidelines are not restrictive. However, this finding was identified in interviews with developers, demonstrating Q method's ability to smooth divergent views which makes it possible to establish a clear narrative. At the same time, the factors establish that different groups of actors value different elements for industry development.

Further generalisability of these findings would be possible with a larger sample size or through conducting the Q Method in another region, making it then possible to control for the actor-type experiences and the impacts of regional characteristics. The Q Method confirms many of the assertions of the analytical narrative and at the same time provides additional insights. It can be concluded that regional embedding and collaboration will be important for industry progression. The full range of evidence will now be explored in relation to the themes developed in the literature review in Chapter 2.

8.3 Geography in a transition

8.3.1 The institutional framework

The literature review established the likely role of geography in a technology transition with research question 1 seeking to better understand the relationship between region and technology. The remainder of this chapter will explore the theories outlined in Figure 8.1 (originally found in the literature review as Figure 2.2), outlining the way in which the region influences the framework within which a technology is developed, and a transition unfolds.

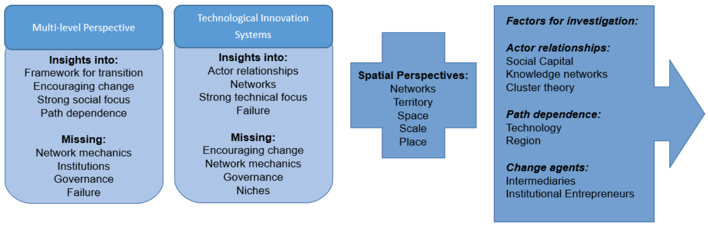


Figure 8.1. Towards spatial perspectives in transition research.

Source: Author's own

The market creation, innovation support and technology embedding analysis chapters evidence how regional characteristics impact innovation: WG energy policy seeks to correct regional development issues; ERDF monies are utilised to stimulate innovation; and the recognition that incumbent industries face a declining trajectory elicits action on the part of actors. These stimuli all stem from the less-developed regional context of Wales.

Regional heterogeneity introduces variables that shape a transition, and the RE transition in Wales focuses on the ability to attain growth and employment objectives. In this context, the economic rather than environmental element of sustainability comes to the fore for many key governmental actors. WG policy requires that "business delivers on the promise of jobs from investment into energy" (Welsh Government, 2012c, p.16) and plans to develop a supply-chain that can "help unlock our own energy resources and export energy-related expertise" (Welsh Government, 2012c, p.16).

It could be suggested that cost-effective energy transition and maximised regional economic development opportunities are not easily achieved together for ME, particularly in the context of Wales as a less-developed region. This said, it is unlikely to occur for RE in most locations – very few locations will host innovation 'winners' - and suggests that there are trade-offs between innovation support and regional economic development goals. Evidence of this would be the EU funding managed by WEFO pre-Brexit, where stipulation of local supply chain use boosts regional goals but when the right regional supply chain company cannot be found, it has the potential to hamper innovation.

Wales' path-dependent tendency, shaped by UK policy, to support a trajectory of low-cost electricity further contributes to the slow evolution of policy support for ME. This perhaps aligns with Strategic Niche Management that champions a co-evolutionary approach to ensure that the technology matches the established socio-institutional framework (Freeman and Perez, 1988). However, there is a need to also change the framework – no technology in Wales promises the ability to have large-scale centralised RE production. This research finds that the less-developed status of these regions, and a need for jobs and growth has meant the mobilising of resources behind existing industries. In this respect, more steadfast support for the MEIW does not need to incur financial cost and there are now actions to provide support to the MEIW through WG's legitimation of MEW.

However, other technology trajectories intersect to generate support for the development of the MEI. The decline in oil demand comes as part of the wider environmental initiatives being driven by the UK Government and WG; arguably this enforced decline is creating an impetus for the change emerging in Pembrokeshire. Whilst there is no sign of this at the time of writing (March 2021), were the UK Government to decide to step away from nuclear as is the case in the Energiewende initiative in Germany (Beveridge and Kern, 2013; Rogge and Johnstone, 2017), it is possible to suggest that an increased appetite for marine or other RE sources might be witnessed in Anglesey. Currently, there is no impetus for

Anglesey's local actors to identify a need for economic transition and path change, leading to diminished support for the energy transition.

Significantly, this research has found that deficiencies in the institutional framework need not inhibit transition. Where other research has found a history of institutional thinness in Wales (Marques et al., 2019), due to multi-level governance and devolution there is an abundance of institutions and governmental actors that engage with the MEIW. However, the misalignment comes from policy priorities, stretched resources, and a lack specific actors to lead innovation. The analysis found that there is not one governmental actor that has significant influence or ambition over the range of functions and institutions that constitute the socio-technical system to drive a ME transition.

With these institutional deficiencies, the evidence surrounding MEP and MEW suggest that in contrast to existing theorising of the need for a great variety of actors (Trippl et al., 2018; Grillitsch and Nilsson, 2015), this is only a need for some that are committed to enabling change. This runs counter to the hypothesis that the low number of actors in a region will be the most significant regional characteristic. This said, where Section 8.5.2 will discuss the formation of an institutional entrepreneur in Wales, perhaps many of the functions fulfilled by MEP and MEW could have been carried out by WG directly as had been postulated in Section 2.7 that elaborates the theoretical argument in response to the research questions. However, this degree of adaptation and knowledge capability may be more difficult to achieve by a central institutional actor in a less-developed region (Hansen and Coenen, 2015)

8.3.2 Regional change

The evidence has established that the MEIW is subject to the influence of actors with different goals ranging between innovation, regional development, and industry preservation. This section will consider the evidence of path dependency in Wales, cluster creation, and finally whether transition is taking place with new path creation. It will further elaborate on the characteristics of a less-developed region and its influence on sustainability transition (research question 1).

Within the institutional framework of Wales as a devolved nation, the heterogeneity of the subregions has enabled the consideration of different institutional pressures. The two NUTS3 regions within Wales (NUTS1) show different strategies that may be employed to secure economic benefit. This geographical differentiation despite the uniformity of the territorial institutions comes as a result of agency (Gailing et al., 2020); this evidence can contribute to theory building as to the conditions in which transitions are more likely to occur.

	Pembrokeshire	Anglesey
Economic development	Less-developed region	Less-developed region
Niche presence	Numerous niche technology actors with embedding highly encouraged by regional actors	A few niche technology actors with little embedding encouraged by regional actors
Regime presence	Present but declining	Present but declining
Regional assets	Wave and tidal resources, wide range of supply chain companies within NUTS3 region, electricity infrastructure	Tidal resources, some supply chain but reliant on neighbouring NUTS3 regions, electricity infrastructure
Regional vision for future	Regime will not be resuscitated – focus on path creation and industrial diversification	Potential for regime to be resuscitated – path dependent focus on prolonging regime technology
Actors and agency	Niche technology intermediaries	Actors use agency to support regime technology
Embeddedness	Development of wide range of activities encompassing supply chain, knowledge network development, testing infrastructure, and enactment of centralised initiatives – pointing to cluster development	Enactment of centralised initiatives – limited evidence of additional embedding activities in the region

Table 8.2. Comparison of NUTS3 regions in Wales and marine energy activity.

Source: Author's own.

Table 8.2 outlines that the principal differences between Pembrokeshire and Anglesey are agency, embeddedness, and regional assets. The technology embedding analysis suggests that activities in Pembrokeshire are more likely to generate a regional dynamic within which technology developers are likely to remain once at a higher technology readiness level. This can be attributed to the actors and networks that are centred on ME technology, where new energy spaces require new actor networks, in turn making it more possible to use RETs for economic development (Gailing et al., 2020). Conversely, in Anglesey, the actors mobilise around expectations of the continuation of the pre-existing nuclear energy industry, which marginalises regional integration of ME technologies due to an absence of social capital and institutional support. This shows how competing visions of the future shape place as a site of transition (Murphy, 2015).

Anglesey displays path dependent tendencies with the privileging of nuclear in the region, despite the advanced technology readiness level of an innovative ME technology. There was a belief in the possibility of retaining nuclear which was an existing industry in the region. Regional activities focused on this type of energy at the expense of nurturing relationships with the MEI. Additionally, until early 2020, the prospect of new nuclear reinforced the WG strategy of supporting industries that have significant employment numbers. This thinking is evident within Anglesey's local government actors.

Going forward, the social capital development by Menter Morlais will be pivotal for regional embedding and is needed to balance the higher degree of geographical embeddedness of nuclear as a regime technology (Bridge et al., 2013). However, an existing lack of commitment to nurturing social capital by the regional institution and the intermediary that they chose to act on their behalf is widely perceived by developers. Transition research gives limited attention to the importance of networks, but increasingly recognises that networks need to be consolidated for the region to seize transition opportunities (Chlebna and Mattes, 2020). This highlights that the ethos of a region and the actors within it can play an important role in supporting the incumbent system's durability (Hansen and Coenen, 2015; Geels, 2011; Cowell, 2020; Aarset and Jakobsen 2015; Isaksen et al. 2018).

In contrast to Anglesey, the evidence in Pembrokeshire suggests that regional decline in the hydrocarbon economy increased the propensity of regional actors to engage with new opportunities. As highlighted in Chapter 7, MEP actors were conscious of the fact that declining regional industry meant that families were being separated as workers moved away. MEP actors were also aware and accepted that this decline was inescapable and sought to mobilise change. In forming MEP, Pembrokeshire Coastal Forum continued its path of supporting the region through developing social and network capital.

8.3.3 Path dependency

The Technological Innovation Systems (TIS) literature highlights the evolutionary nature of relationships between organisations and institutions. These relationships support social alignment through discussion of policy and finance support, alongside technical improvement through supply chain and developer knowledge sharing. Section 8.5 further evaluates the changing nature of relationships and knowledge flow within the MEIW. When broadening the assessment of actors from the MEIW to the national innovation system, the spatiality highlights several threats to the MEI technology pathway. Indeed, whilst TIS focuses on the networks of agents rather than 'groups' as within the MLP, the flow of knowledge through the system is crucial.

In Wales there remain institutional deficiencies that sustain the UK focus on centralised energy technology in the pursuit of concentrated job creation, rather than path creation activities to encourage technology innovation and projects within the capacity of a less-developed region. As a result, the organisation of many institutional dynamics centre on the RETs that best adhere to the established socio-technical configuration. Within the MEI, this is exhibited by the persistence in pursuing large-scale technologies, previously the Severn Barrage and currently the Swansea Bay Tidal Lagoon. What is significant about this, as has been demonstrated by the evidence, is the scale of money invested by the WG in projects over which WG, until recently, had no control over the key mechanisms (e.g., consenting). Furthermore, WG did not have the financial capacity to further either of these developments. This highlights the impact of different territorial scales on the innovation system under consideration.

This path dependent tendency is likely to remain problematic for the modular technologies being developed in Wales. Institutional resistance to change could be exacerbated by the extent of infrastructure and system change that is required for ME to supply electricity to the grid. Whilst recent progress in the MEIW has been significant, there is a need for further policy intervention to support industry development. This is apparent in the market creation evidence (Chapter 5) and confirmed by the Q method analysis.

CE has looked to support the market through pre-consented development sites and Milford Haven Port Authority is motivated by supporting the regional supply chain, outlining the importance of embedding in contributing to change. The MLP theoretically attributes CE and NRW as actors that contribute to the landscape existing within an autonomous sphere with abstract goals. The responses of these actors are theoretically "embedded in institutions and infrastructures" (Raven et al., 2012, p.67). The regime and niche actors have no influence over these 'landscape actors' and can only 'unsettle the regime from the outside' (Geels and Schot, 2010, p.23). Yet where a technological transition is considered to take around 50 years (Kanger and Schot, 2016) these institutions have been shown to undertake measures to short-cut some of the more linear processes of scaling-up technology that is much criticised in Strategic Niche Management (Seiwald, 2014).

These relationships have culminated in the development of physical infrastructure that could be considered signs of industry transition in Wales. Niche actors have shared knowledge with 'landscape actors', contributing to the shaping of the demonstration zones, and regime actors are supporting ME technology innovation through testing support. How this has been achieved in Wales and what it means for cluster development will be considered next.

8.3.4 Towards cluster development

The analysis in Chapter 7 shows that a range of actors are engaging with the relevant processes to develop cluster structure in Wales. The MEW interviewee highlighted the goal to create a "cluster"; the evidence shows that the organisation's activities are structured around the concepts of knowledge networks, social capital, and cluster development. These activities are concluded to have a primary aim of embedding developers in Wales in order to draw down regional economic development benefits.

Notably, these efforts towards clustering are not driven by the WG; motivated by MEP and MEW there is evidence of the early stages of cluster development: a growing industry network, engagement of the Milford Haven Port Authority, development of the Marine Energy Testing Area, and the inclusion of ME within the Swansea Bay City Deal. Should a cluster develop in Pembrokeshire, the easy logistics of transporting a device from a dockside workshop opens increasing possibilities. When this is coupled with the regional comparative advantage of deep-water ports, it means there are few restrictions to the size of vessel for transportation.

The MEP has had a pivotal role in providing opportunities for interaction amongst actors and facilitating 'low cost' channels of knowledge, thereby minimising transaction costs. Whilst this is the activity of an intermediary, cluster structures are emerging as a result of the promotion of embedding activities and sharing information on failure. The evidence has established MEP and MEW's success in strengthening the ties in the cluster and encouraging the sharing of knowledge that would typically be considered a 'competitive advantage' (Cassi and Zirulia, 2008).

Despite the low number of supply chain companies currently engaged in the MEI, there remains the potential that the local network becomes increasingly dense over time. The problem of insufficient new nodes for knowledge recombination is not an immediate threat due to the break-through nature of the technology that is being developed. However, in the longer term, the international channels of knowledge that are facilitated by MEW must remain a source of new codified information. Research has shown that the more peripheral a firm, the more likely they are to engage with intra and extra regional collaboration (Jakobsen and Lorentzen, 2015; Teirlinck and Spithoven 2008; Isaksen and Onsager 2010).

In seeking growth and cluster opportunities, the future of the region is in part dictated by awareness of lock-in and path dependency. As such, the early initiation phase of a transition entails the consideration of new possibilities by the current socio-technical configuration (Strambach and Pflitsch, 2018). Supply chain interviewees spoke of capitalising on the region's history of "making money from the sea", but there remains the danger that this precludes other trajectories. What then, can be concluded on whether a transition is indeed taking place?

8.3.5 Is an energy transition taking place?

The emerging question from the research is whether a transition is taking place, and what factors signify this. Whether a niche has been created in Wales or the subregions is perhaps too early to ascertain. It must be asked to what extent there is evidence of the articulation of visions by actors, and the building of social networks and learning processes (Elzen et al., 1996; Kemp et al., 1998). As such, the WG are not creating a niche through policy or any privileging of conditions for the MEI. There are aspects of the institutional environment that the WG cannot control in order to provide a 'protective space', and this includes subsidies. Indeed, the CfDs are shown to have limited impact on technology innovation and there is limited further funding available to developers. Where the WG has utilised ERDF money to support innovation support is evidenced for the emerging nascent technology. However, this technology is pre-commercialisation, and it could be suggested that for a return on this investment to be achieved it is necessary to align further factors to ensure opportunities for carbon reduction and knowledge sale.

It is therefore appropriate to summarise the developments in Wales thus far:

Achieved:

- ✓ Industry knowledge network developed
- ✓ Progression of several innovations supported by EU funds
- ✓ Industry body developed (MEW)
- ✓ Development of infrastructure for next generation of ME technology
- ✓ Emerging cluster
- ✓ Mobilisation of supply chain
- ✓ Evidence of social capital and knowledge sharing
- ✓ Evidence of some institutional reconfiguration and support for industry (CE and NRW)

Not Achieved:

- ✗ Energy to the grid from ME technologies
- ✗ Sufficient Regional policy support
- ✗ Institutional reconfiguration of Government
- ✗ Wide-spread political support for modular ME technologies

MEW is supporting the creation of a niche through the development of a network, fostering of social capital and cluster features. However, the organisation's motivation is that of promoting the MEI rather than change in any wider sense. Indeed, this emerging narrative of conflicting goals within a region highlight a need to elaborate on the regional pathways that interact with transition.

The presence of and engagement with demonstration zones is another encouraging factor as they are likely to accelerate commercialisation as the infrastructure encourages array deployment. In Pembrokeshire, the additional embedding activities undertaken by regional actors and the activities to foster a cluster will complement this physical infrastructure to support knowledge development. These mechanisms could be considered akin to the niches of the MLP that outline the multiple technological experiments and failures that take place before integration into the regime (Geels, 2002).

WG's increasing engagement with MEW also points to transition being in its preliminary stages, the provision of legitimacy signifying long term governmental interest. This engagement could be considered necessary to fully draw down the benefits of the ERDF monies. At the same time, these funds may be limited by Brexit, with no replacement funding announced. This suggests a risk to continued industry development in Wales and future generations of ME technology. The evidence has highlighted that EU funding attracted developers to locate in the region, and in the absence of these funds and with limited capacity to replace them as a less-developed region, alternative mechanisms are essential. These mechanisms include policy support, knowledge sharing facilitation, and embedding efforts.

As such, the picture of ME transition in Wales is at best uncertain, it is not yet possible to ascribe the process a success, yet the recent progresses in embedding and technology development signify that the innovation process continues and has not come to an end. The outcomes achieved by these actors include the legitimation of MEW, the development of cluster-type activities in Pembrokeshire, and the deployment and testing of seven technologies from Welsh developer bases. Whilst it is not possible to ascertain whether all actors have sustainability goals in mind; there is the possibility that in a less-developed region, there is a higher imperative on the transition addressing the three tenets of sustainability. Understanding the methods by which relationships are formed and how they contribute to the MEIW will feature in the next sections.

8.4 Actors' role in engaging with the socio-technical system

8.4.1 Introduction

The evidence confirms that one of the key benefits of Wales as a small region is the ability to co-ordinate activities. The evidence highlights a range of actor relationships throughout the region that have varying degrees of power in mobilising a transition. This section will consider the relationships and knowledge sharing hypothesised in Chapter 2 against the evidence to better contextualise their influence in the MEIW, exploring research question 2 in greater detail.

8.4.2 Relationships

Based on the transition, innovation system, and actor literatures, the literature review theorised the likely relationships involved in shaping the development trajectory of the MEIW. The evidence both confirmed a number of these hypotheses and discovered nuances that were specific to the case study - likely due to the less-developed region. There is, however, the possibility that these differences are due to the pre-commercialisation status of the technology explored or the nature of the regional actors. This section will consider how these differences, summarised in Figure 8.3, might affect generalisation around ME, less-developed regions or sets of causal mechanisms within transition. Those observations and arrows in bold are considered new findings in the research, those that are not in bold confirm what was hypothesised in the literature review.

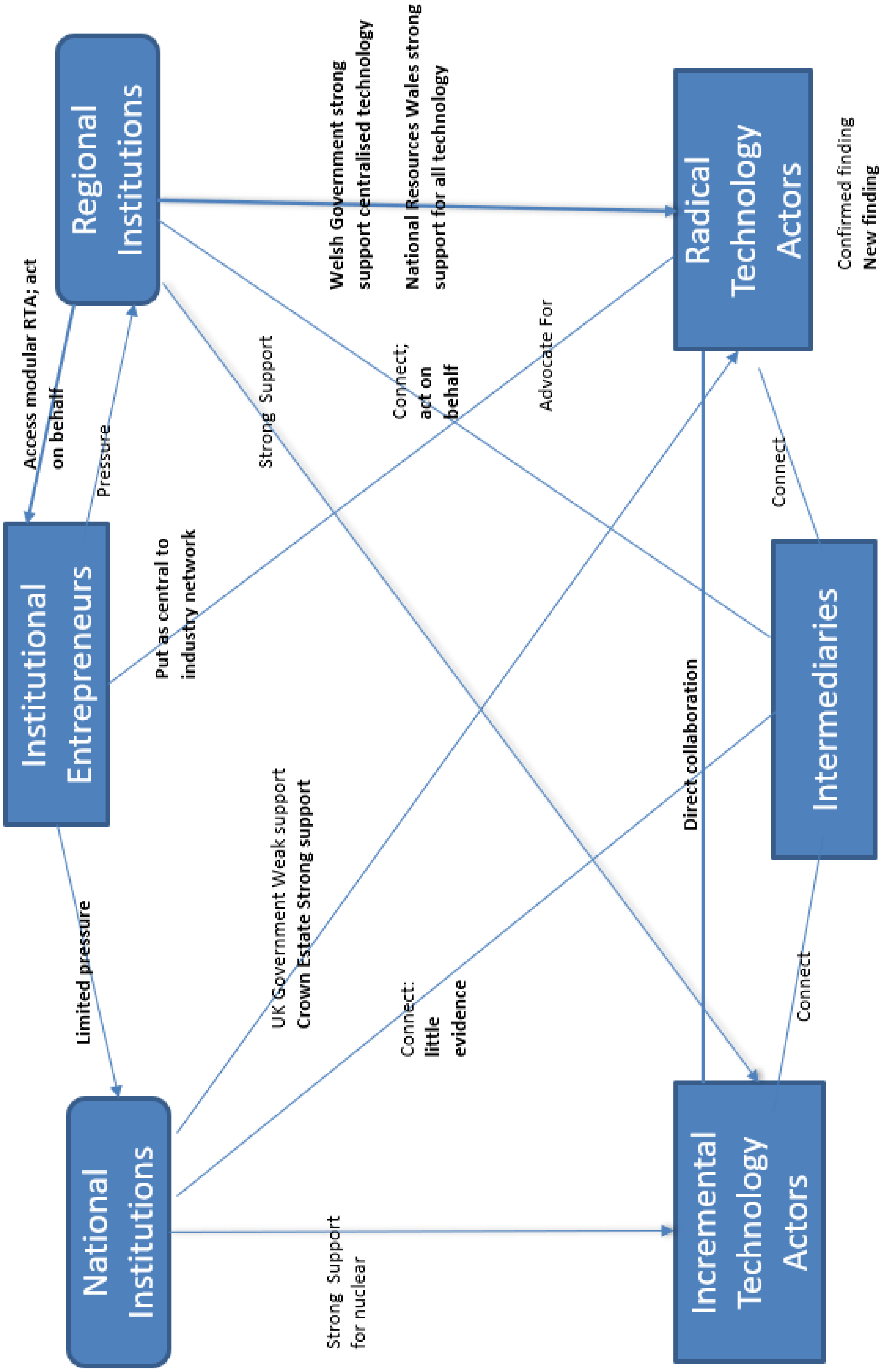


Figure 8.2. Relationship evidence in MEIW.

Source: Author's own.

Figure 8.2 evidences how geography is important to the very dynamics of transition. The evidence suggests that the UK government as a national institution is largely impervious to pressures from radical technologies and does not seek to foster relationships. These radical technologies are largely pursued in the regions and could be considered remote from this centralised power. At the same time, WG and its policies as a regional institution can be ambiguous in supporting the industry, with limited direct relationship with the modular technology developers. A regional specificity perhaps influenced by the activities of the UK Government.

As suggested in the literature review (Chapter 2), the research confirms that there is strong support by the national (UK Government) and regional (WG and Anglesey County Council) institutions for the 'Incremental Technology Actors'. This level of path dependent tendency is an expected finding due to the lack of industrial diversification in Wales, which could be considered typical of a less-developed region (Trippl et al., 2018). In this instance, institutions will seek to support established industries - the UK Government does so with conceptions of energy security central to their motivations, and WG does so with job protection. This means, for example, that whilst there are institutional moves towards 'low carbon' energy, the incumbent nuclear power generation in Anglesey region dominates Welsh discourse.

With respect to the 'Radical Technology Actors' it becomes apparent that the devolved nature of ME consenting adds layers of interaction and complexity. Ideally, to support industry progress attempts should be made to streamline the pathway to change through fewer, more effective relationships; this could potentially occur in Wales due to the proximity of regional institutions to the industry and is evidenced to some extent by NRW. This said, the strength of these relationships is now at risk with the introduction of the charging system for advice. Whilst this is a decision that has been made by the organisation across the board, at the current stage of technology readiness level the charges and associated diminution of relationships that are a source of informal advice are likely to create further institutional blocks.

The divergence in the approach by national institutions (CE and UK Government) is apparent. The anticipated weak policy support on the part of the UK Government to 'Radical Technology Actors' is countered by the strong support and important assets proffered by the CE to the MEIW. Arguably, the strength of this relationship and efforts undertaken by the CE to develop a dialogue with the MEI are driven by the possibility of future rents. Moreover, the support that was devised by the CE for the MEI is applicable across the UK and not unique to Wales as a less-developed region. The demonstration zones ease the CE's own burden in managing licencing applications whilst simultaneously addressing CE's monopoly position - providing a significant boost to the industry.

There is a similarly divergent relationship between regional institutions (WG and NRW) and 'Radical Technology Actors'. Whilst it was anticipated that the strength of connection overall would be 'medium', there is a polarisation with the WG having a strong connection with large scale technologies such as the Swansea Bay Tidal Lagoon that better match established technology trajectories of centralised power. The WG's relationship with the modular technologies is weak and was moderated first through MEP and then increasingly through MEW. The evidence highlights the likelihood that governments in weak economic areas are less likely to engage with change as pursuing jobs creates a great deal of conservatism. This confirms the policy path dependence that is evident in much of the WG's approach within Wales (Morgan, 2017).

Whilst the institutions in Wales have made extensive use of intermediary organisations, the supply chain and developers have utilised a combination of intermediaries and direct contact. MEW is central to many of the relationships, where the 'Radical Technology Actors' utilise MEW to add strength to their voice. Yet, much like NRW, the introduction of membership fees has the potential to alter this. This would jeopardise the viability of the WG's strategy to invest social capital capacity into developing a relationship with MEW rather than directly with developers. In these instances, this is due to business model evolution on the part of MEW, but for NRW could be attributed to austerity.

This section has highlighted how the relationships in the MEIW have evolved, where actors co-ordinate activities to support innovation and draw down regional benefits. What then is the nature of the knowledge network structure and information shared?

8.4.3 Network structures and knowledge flow

In contrast to the findings on relationships, much of what was hypothesised about knowledge flow was apparent in the case study. Summarised in Figure 8.3, there are nuances due to the region and actor types, bold arrows and text outline new findings.

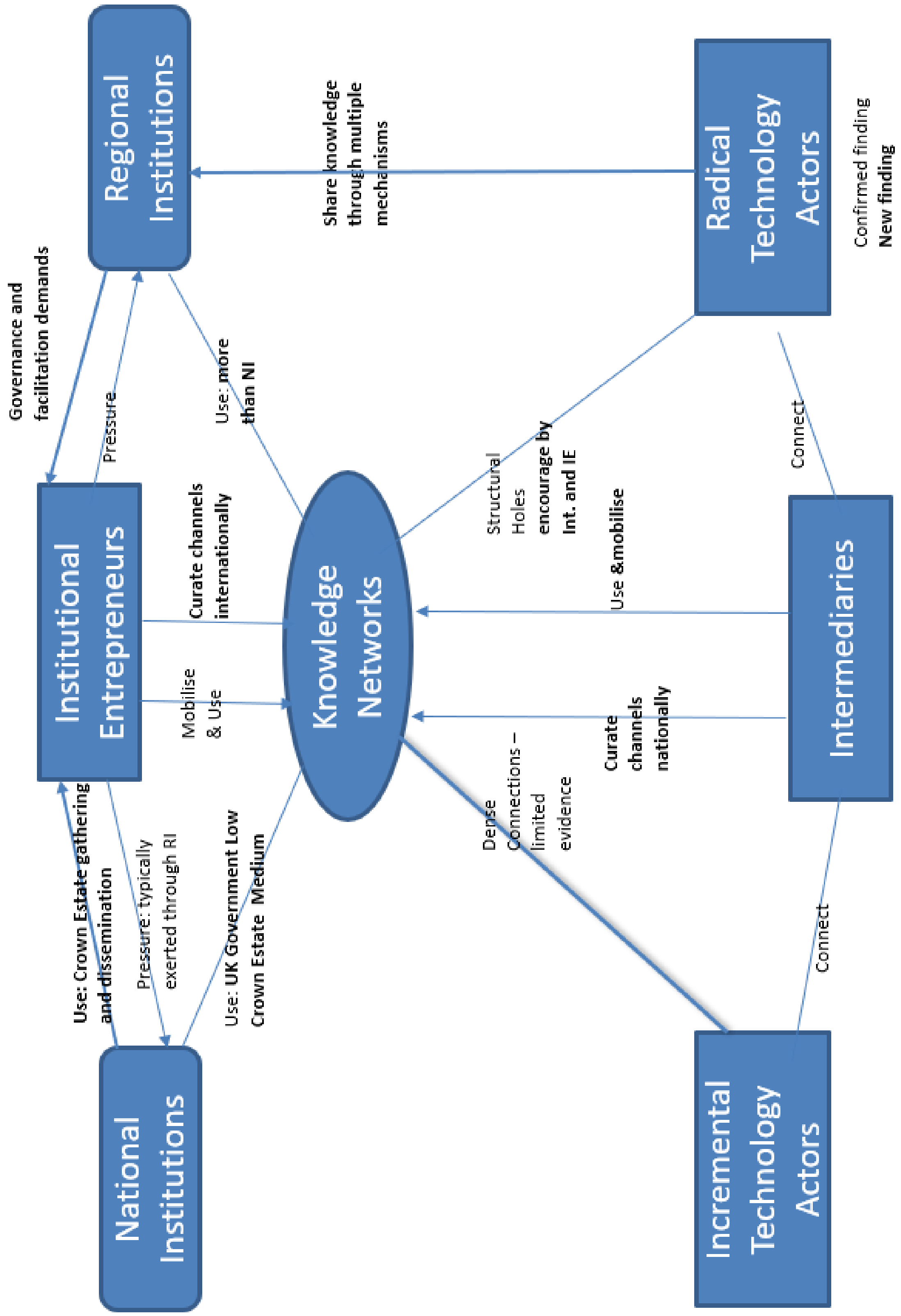


Figure 8.3. Knowledge network evidence in MEIW.

Source: Author's Own.

Knowledge is shared with the WG through initiatives such as the Task and Finish Group and policy consultations. In a similar fashion to the relationships it maintains, WG seeks knowledge from MEP and MEW – attending the annual event, the working group on occasion and commissioning MEW to undertake information gathering exercises for policy consultations. Developers viewed this as effective in having a unified voice as an industry and was timesaving for those who were unable to respond directly to the policy consultations.

Regional institutions (WG and NRW) were seen to utilise knowledge networks to a greater extent than the national institutions (UK Government and CE), with limited evidence of UK Government policy consultations undertaken directly with developers. However, much like NRW, CE utilises the network created by MEP for knowledge gathering and dissemination. Through attendance at the annual event and working group meetings, the CE gathers knowledge on industry requirements.

However, the evidence suggests that NRW mobilises the Welsh knowledge network to a greater extent due to a greater need to do so. As highlighted in the market creation analysis (Chapter 5), CE are responsible for the initial approval of areas of the sea for exploitation with much of the remaining licensing details resolved by NRW. However, as highlighted in the previous section the quality of social capital furnishing this knowledge sharing may decline with the introduction of charging, impacting the nature of the information shared.

The literature highlights the importance of network structure for the possibility of innovation. A significant finding is how the MEP and MEW curate the network. In this way, developers who are from outside the region are matched to these groups through MEP's work as a NUTS1 and NUTS3 regional intermediary. It is perhaps the new knowledge of an 'outside' developer interacting with the denser network of the region that provides the greater opportunity for progress. When these dense networks have expertise in both the marine environment and energy, it is likely to be a better foundation for success.

Further, the MEP and MEW introduce global channels of knowledge through fostering relationships with other organisations. As an intermediary, MEP focused on national channels including organisations from Orkney - establishing best practice for MEP positioning and activities in Pembrokeshire. Going forward, MEW has expanded these channels internationally to include co-operation with Ireland and Canada. These channels will be important not only for knowledge inflow but also knowledge export for MEW and the MEIW more generally. Supply chain companies may become more motivated to diversify into ME technology due to the increased opportunities. The inclusion of MEW on trade missions by the WG will also help raise awareness of the resources and technologies. The pervasive nature of the activities of the MEP and MEW within Wales are apparent, leading to the necessary summary of the actions and achievements of intermediaries and institutional entrepreneurs in Wales.

8.5 Actors and transition

8.5.1 Change agents

Research question three seeks to interrogate how actors co-ordinate activities to secure economic development benefits from innovation-driven sustainability transition. Where some actors have sought to create market stability, other change agents have focused on mobilising knowledge networks or exerting pressure on institutions and governmental organisations to change.

The interviews outline that the perceptions of how the governmental organisations work are different, for instance CE and NRW are considered by the industry to be interactive whereas WEFO were viewed somewhat as operating ‘by the book’. Whilst developers were at pains to assert that the money received “from WEFO” was invaluable to supporting technology development, the difficulties encountered navigating the organisation were clear.

In the context of this study situated in a less-developed region it is possible to understand whether a particular type of actor is more adept at promoting change. Indeed, the role of intermediaries in a transition is complex, where the changing role of actors is evident, so too are the role of transition intermediaries subject to change (Hyysalo et al., 2018). It is possible that there are 'ecologies of intermediaries' in different stages of a transition (Kivimaa et al., 2019b; Kivimaa and Martiskainen, 2018; Martiskainen and Kivimaa, 2018; Mignon and Kanda, 2018).

Where the process of institutional change is gradual, so too is the emergence of institutional entrepreneurs who adapt existing arrangements to new configurations to support path creation (Strambach, 2010; Sotarauta and Pulkkinen, 2011). This section will also consider the role and emergence of these types of actors.

8.5.2 Intermediaries

There is evidence of two types of intermediary in Wales, the Offshore Renewables Joint Industry Programme (ORJIP) Ocean Energy programme of work (Iles and Yolles, 2002) and the MEP-developed network (van Lente et al., 2003). ORJIP Ocean Energy further highlights CE's responsiveness to the development of the MEI across the UK, with progression of the industry in Wales as a further benefit.

Indeed, it could be suggested that CE is a transition intermediary focused on systemic change due to the wide range of market creation mechanisms the CE institutes to configure and enable the pre-domestication of this technology. These changes include the creation of the demonstration zones and the initiation of ORJIP Ocean Energy so governmental organisations from across the UK can share information. As such, the CE could be thought to seek to identify the factors that may act as an impediment to industry development, driving governance mechanisms towards goals. This said, no one actor has sufficient resources to control a regime and these actors are bound by resource interdependency (Smith et al., 2005). In this instance, and to navigate the complexity of a transition in a less-developed region, the evidence suggests that the presence of other intermediaries is also necessary. This aligns with the developing literature on ecologies of intermediaries (Martiskainen and Kivimaa, 2018).

The MEP could be classified as an industry group that started with a focus on technology embedding in order to promote regional economic development. The activities of this group evolved into that of an intermediary following realisation of the level of support required for industry development. As an intermediary MEP focused on connecting local projects, aligning with regime priorities, and promoting the diffusion of knowledge (Kivimaa et al., 2019). This research finds that MEP has gone beyond the functions of knowledge diffusion, becoming a knowledge gatekeeper by seeking out new knowledge that may benefit the niche. Therefore, it could be argued that as MEP's activities extended to exert pressure on institutions and enact further change, the actor became a more important transition intermediary.

It is interesting to consider the central role that has developed for MEP. Initially the industry, and eventually the governmental actors, elected the organisation as a central point mediator between the two groups. As evaluated earlier in this chapter, this to some extent relates to absorptive capacity, with MEP adopting a bridging role for many of the actors (Isaksen et al., 2019).

The literature also highlights the danger of intermediaries making themselves obligatory points of passage as part of their business model (Latour, 1987). However, this does not seem to be the case as MEP worked 'at risk' for many years with no pecuniary recompense for activities. It is only once the organisation evolved further to include the institutional pressure element and become MEW that charges were introduced. Does this inclusion of institutional pressure and evolution to Marine Energy Wales (MEW) position the organisation as an institutional entrepreneur or simply one that undertakes institutional entrepreneurship activities?

8.5.3 Institutional Entrepreneurs

Marine Energy Wales (MEW) was born out of the work of MEP. It is notable that whilst notionally MEP and MEW remain two separate organisations, MEW has taken over many of the activities of MEP including the working group and annual conference. The individuals in the team behind the organisations also remain similar, meaning a high level of retained social capital within the organisation and with other actors. This suggests an evolution of the actor and highlights some of the key characteristics considered necessary to support the industry in Wales. Indeed, actors within a region have specific knowledge and relate their practices to this context (Faller, 2016). As concluded in Section 8.3, new path creation can be observed, and the evidence points to emerging system transition.

MEW has some characteristics of an institutional entrepreneur. In order to understand the formation of this actor and to ascertain whether its form has changed or simply taken on new activities (Hoogstraaten et al., 2020), a multi-stage analysis was undertaken of the activities of MEW. This additional analysis utilises evidence from the interview commentary, Q method analysis, and observations of the activities that the actor undertakes.

Figure 8.4 summarises this analysis in a pairwise formation, aggregating the data into 'higher level orders'. This extends previous analysis as it seeks to define which of the many activities undertaken by this actor can be considered institutional entrepreneurship over and above 'intermediary-type' activities. Second-order themes then collapse the activities observed in the first-order analysis into a synthesis that anchors both empirical and theoretical observations. The second order themes outline the institutional work undertaken, and broadly occurs at three distinct stages of progress towards institutional entrepreneurship, as highlighted by the third order.

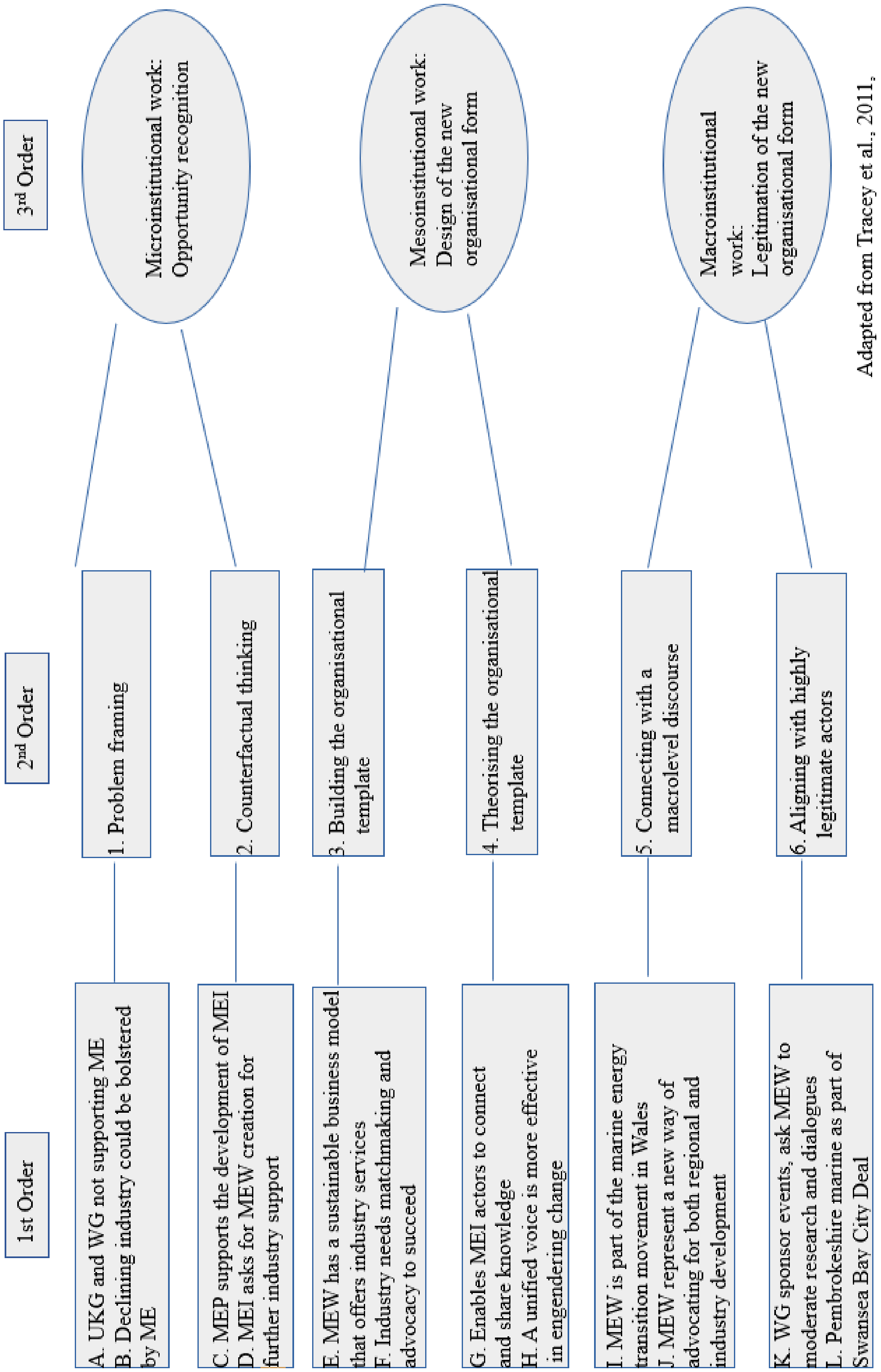


Figure 8.4. Creation of an institutional entrepreneur.

Source: Author's own.

The third order work aligns with the functions of system transition, where microinstitutional work to recognise an opportunity relates to path identification and understanding of the mechanisms that are missing in order to promote change. Mesoinstitutional work and design of the new organisational form includes the ability of an organisation to identify required characteristics and functions to address missing mechanisms. At the macroinstitutional level the legitimation of the new organisational form also creates increasing legitimation of the transition. The MEW shares its vision as an organisation seeking to encourage ME development and engages others in these activities. At the same time, the WG's involvement with the MEW legitimises this actor and in turn legitimises the MEIW.

This form seems to seek to compensate for institutional deficiencies as the MEW engages with many roles to meet divergent actor demands. Indeed, Multi-level governance has created competing demands that are incompatible with the radically different technologies that need developing – cheap, decarbonised energy that creates a high level of employment. To some extent, this is a dependence on a narrative from the hydrocarbon industry that externalised many of the environmental impacts.

Research highlights that institutional entrepreneurs are not disembedded agents but need to gain the support of other actors (Battilana et al., 2009). In this respect, the work undertaken by MEP provided the self-organising networks through which to promote change. MEP utilised its social position to engage with a range of activities (Faller, 2016; Pelzer et al., 2019) to mobilise both market creation and innovation support mechanisms. The formulation of the MEP network identified the project which gained backing (Dorado, 2005), and through an accumulation of actions and momentum, the organisation gained higher visibility. Following this greater visibility with WG, MEP was able to persuade others of the need to co-ordinate activities and devise a solution to the problem as highlighted in Dorado's (2005) work. When seeking to resolve this problem for Pembrokeshire by highlighting the overall structural issues experienced, others became convinced of MEP's ability to act for Wales.

8.6 Conclusions

This final analytical chapter draws out some of the key themes that emerge from the sum of the market creation, innovation support, and technology embedding analysis. When working towards a system transition, the evidence makes apparent the requirement of activities across the range of mechanism types. The Q Methodology highlights that these types of mechanism will be valued differently amongst individuals. However, key areas of action emerge in Wales. The value of MEP and MEW as actors that have been influential for industry development, and the impact of these organisations are apparent throughout this chapter. As such, they can be concluded to be important regional characteristics particularly in the Pembrokeshire sub-region.

Collaboration is an integral part of the MEIW and is reflected in the relationships and knowledge sharing that characterise the industry, aspects that were hypothesised to be important to progress both innovation and transition. Significantly in Wales, the universities are not credited with providing sufficient 'hands on' knowledge, and there is demand on the part of the industry for ready-prepared data. This is a missed opportunity, particularly in a less-developed region where it is posited that new opportunities are harder to pursue due to a low number of actors. The provision of data could be achieved by the universities, NRW or other institutions, suggesting a gap in institutional effectiveness. Usefully, failure is viewed as an opportunity for learning, and the flow of knowledge is well established within the industry. However, much like other innovative technologies, financial issues are apparent in the MEI.

Many of the factors that could be considered problematic for innovation are influenced by the less-developed status of the region, and the industry considers that WG policy does not sufficiently support the development of the MEIW. In turn, these factors create challenges for innovation-led sustainability transition. It can be argued that the demands of the multi-level governance arrangement create policy requirements that make transition increasingly difficult. This regional heterogeneity that seeks growth from a green transition creates a demand for actors that can navigate the system.

Theorising that a less-developed region provides the opportunity for niche creation, it is possible to conclude that there are some early signs of a proto-market at a UK level in the sense that infrastructure is being put in place to support innovation and the route to market. Where the technology has not yet made it to market thereby confirming the efficacy of the niche, it is possible to conclude that this activity alongside the Wales level cluster development and legitimation of institutional entrepreneurs are indicators of a still unfolding transition.

This transition relies not only on the successful development of pre-commercialisation ME technology but also the reconfiguration of infrastructure to enable the integration of this technology into the established socio-technical system. This change and path creation has been achieved through a range of mechanisms that principally hinge on ERDF funding, the consenting activities of CE, and the network-developing activities of MEP. Yet literature infers that regional policy makers should be the principal proponents of this system change to achieve the best outcome.

Within the region, as anticipated, actor relationships as anticipated are stronger between 'Incremental Technology Actors', reflecting strong path dependent tendencies within Wales. However, CE and NRW are institutions that are adaptive and foster effective relationships with 'Radical Technology Actors' around the de-risking of spaces for technological development. What is apparent is the sheer number of relationships that 'Radical Technology Actors' must maintain with institutional actors without counting the relationships they need to maintain for innovation. Whilst transaction costs are noted in the literature, the complexity of the relationships are striking. It seems therefore inevitable that an intermediary would become important through facilitating the reduction of transaction costs. In much the same way, as an institution in a less-developed region, WG utilises intermediaries to also minimise the number of relationships that it must maintain.

The knowledge network broadly emulates the relationship network, which was expected, but it is important to note that MEP creates and maintains channels with varying external sources of knowledge. This will be key to avoiding lock-in within the industry and the region (Uzzi 1996; Boschma, 2005; Bathelt et al., 2004). This comes in light of the very apparent path dependent tendency on the part of the WG, where the market creation mechanisms exerted are not consistent and therefore require greater action on the part of other actors. This shows that in the context of weak institutions, there is a compensatory relationship between the different change mechanisms. How these transition mechanisms contribute to change and the wider implications of the observations of the MEIW will be explored in the next, and final, conclusion chapter.

Chapter 9 Conclusions

9.1 Introduction

This thesis has explored the influence of regional characteristics on sustainability transition, aiming to contribute to our understanding of the socio-cultural and political struggles of a technology over time (Geels, 2019; Lie and Sørensen, 1996). Exploring ME in Wales, a less-developed region, the evidence has established how regional actors seek to draw down regional economic benefits at the same time as facilitating transition towards greener energy technologies.

A critical realist stance has been adopted to the study, formed from an interest in the events and activities undertaken in the pursuit of transition goals - entities are considered for their causal powers (Aastrup et al., 2008). These entities, that include institutions, businesses, and networks, are explored through secondary data analysis, semi-structured interviews and Q method. This conclusion chapter summarises the key findings in relation to the research questions that were posed, providing insight into the relationships between the region, sustainability transition, economic development, and technology trajectories. Then, wider reflections on transition will be considered followed by suggestions for future research.

This thesis sought to challenge several perceptions within the transition literature, established not least because methodologically they have focused on transitions that have already taken place with little attention to regional dimensions. This thesis has engaged with a transition whilst it is taking place, highlighting that it is possible to study technology trajectory change before the technology reaches the market. This research has, however, highlighted a need for research adaptability and adoption of a wide range of research methods.

Importantly, this research has established the integral role of regional characteristics in a transition - how these characteristics influence the regional trajectory, and in particular how key agents can compensate for institutional deficiencies. It is also evident that the goal of a change agent need not be sustainability transition. However, whilst individual actors are shown to impact the transition, it is the network that is mobilised that has the most significant impact on change. The activities of industry actors coupled with the policy and activities of governmental actors create momentum. In particular, the government must provide legitimation to private sector activities through the provision of funding, sponsorship of events, and endorsement of actors or technologies to enable a networked approach to change.

9.2 Contribution to the literature

9.2.1 Introduction

The analysis has established that in the context of a less-developed region, there is a great deal of social and political action required to encourage transition and make a natural energy resource exploitable. This follows the research aim to understand how regional characteristics influence sustainability energy transition, paying attention to the role of actors in supporting the innovation process. In the context of a less-developed region, are aspects such as securing economic benefit more important than supporting innovation processes? The three research questions were discussed extensively in the context of the case study region of Wales in Chapter 8. This section will summarise key findings and then reflect on their wider applicability.

9.2.2 Regional characteristics

> RQ1. How do the characteristics of a less-developed region influence sustainability transition?

The literature review established that work on the local model of transition (Geels, 2019) will bring about better conceptualisation of transition activities and mechanisms. It is increasingly apparent that regions can be "re-made" during a transition (Murphy, 2015). What too, about resistance to change in regions with an abundance of exploitable natural resources? The evidence points to the range of endogenous dynamics within a region that are social, economic and political (Bristow, 2010; Barnes, 2011) that contribute to the pursuit of new regional path creation and the activities that must be undertaken to make this a success.

Where geographical unevenness is typically explored in urban regions and developing countries (Binz et al., 2020; Furlong, 2014; Wieczorek, 2018), the multi-scalar conceptions (Coenen et al., 2012) of investigating transition in a less-developed region has uncovered insights into the dynamics of system transition. Throughout the research, regional heterogeneity and the influence on transition is apparent, with the findings contributing to the field of the geography of sustainability transitions.

Crucially, the findings highlight that there is a divergence in outcomes in the subregions of Wales. This shows that even within the same broad governance and political framework of a less-developed region, there are further subregional characteristics that influence transition. It can be seen how the alignment between institutional goals and new technology can vary across places, determined by both the market and institutional set-up (Van de Ven, 1993; Davies, 1996; Jacobsson and Lauber, 2006). This highlights how place politics and the actors within these spaces can be important in the support or challenge of the incumbent system. This asserts the merit in research that contributes to the development of theory and expansion of literature in the subject area of technology trajectory transition.

Emerging from this comparison, five principal regional characteristics have been shown to influence transition dynamics: economic development status; perceived incumbent technology potential; actors; institutions; and the supply chain. Section 8.3.2 detailed the differing approaches of the two NUTS3 regions, making it possible to conclude that where it was hypothesised that actors would play the most significant role, the economic development status of a region and the status of the incumbent industry are the defining characteristics of the region's approach to transition. The evidence adds to the literature through highlighting that in the same territorial context, beliefs about the likelihood of continuation or revival of the regime technology can strongly dictate regional activity and transition. These pre-existing characteristics influence the subsequent decisions of key actors along this new technology trajectory (Martin and Simmie, 2008).

A secondary feature to the economic development and incumbent industry status of the region is the challenge of limited specific institutional support and leadership. Where it was postulated that in Wales as a less-developed region an opportunity for innovation would be supported by the WG through rendering the region attractive to innovators, the evidence shows that this takes place in a limited manner due to the perception of risk. This risk is deemed too significant for those that lead a less-developed region. The evidence does confirm, however, the notion that the government would work with the industry and other actors within these regional spaces to become promoters of sustainability transitions (Truffer and Coenen, 2012).

TIS literatures asserts the necessity of alignment between institutional goals and new technology, and the resources that can be dedicated to this may vary due to the economic development status of the region. The evidence shows that a pre-commercialisation industry may face significant challenges in meeting institutional goals that prioritise economic growth. It can be summarised that all actors undertake activities in the context of the level of economic development, with growth and employment as primary motivators. Some actors respond to these challenges by pursuing portfolio diversification with a new technology and others seek to preserve the incumbent regional pathway, ignoring innovation opportunities. This is evidenced by the supply chain diversification in Pembrokeshire against the over-arching support for nuclear by government actors in Anglesey. As a result, it can be concluded that in the context of sustainable transition driven by energy technology innovation, regional characteristics can shift the focus from transition to mechanisms related to innovation.

The research presented here also shows that the supply chain supports transition in a regional context due to the localised knowledge that individuals possess to which they relate their practices (Faller, 2016). In this case study, supply chain companies have knowledge of the marine environment and how the products they create interact with the sea conditions, reflecting findings that suppliers can be important partners in innovation collaboration (Jakobsen and Lorentzen, 2015). It could therefore be suggested that how supply chain companies contribute to local place-based networks is underestimated in transition literature, which tends to be innovation-centric. The networks that these actors are a part of, and the knowledge that they share are all place specificities that contribute positively (and negatively) to change. The evidence confirms the hypothesis that the adoption of cluster principles and the development of networks within a region will have a positive impact. Further, the evidence shows that supply chain organisations negotiate a range of challenges whilst engaging with nascent technology. This ranges from support with business plan development to technical design input, showing that the supply chain can play a critical role as an actor within innovation and transition.

Whilst the two NUTS3 subregions in Wales are within the same territorial scale, it is apparent that issues of territoriality and multi-level governance at a NUTS1 regional scale have meant that the market creation activities undertaken by government have had divergent outcomes. These competing levels of territorial control have made some mechanisms less effective and generate a need for regional activities to compensate. This suggests that attention should be paid to how policy demands at multiple levels interact and shape the technology trajectory. In the context of Wales, it has been found that achieving low-cost RE that at the same time creates a high number of jobs are two competing and unlikely goals.

When contrasting the activities in the two NUTS3 regions it is apparent, as hypothesised, that the agency of actors is a significant characteristic. Within these institutionally homogenous regions (Gailing et al., 2020) it can be observed that there is a significant divergence in activities. This evidence confirms that agency is important to regional change (Boschma et al., 2017; Miörner and Trippl, 2017; Isaksen et al., 2018;) and that agents can respond differently to similar regional settings (Zukauskaite et al., 2017).

Where it is acknowledged that the varying potential for transition should be reflected in policy for a region (Hansen and Coenen, 2015), it could be advanced that this happens at a very small scale. It is possible that national legislation creates the opportunity for regional actors to not engage with supporting new path creation, instead favouring the incumbent system. Where the role of policy is to stimulate infrastructures for innovation (Njøs and Jakobsen, 2018), these issues highlight how a focus on actors is essential for understanding scale (Faller, 2016) due to its fluidity (Marston, 2000) as a site of social struggle (Brenner, 2001). As such, predicted governmental engagement must be cognisant of the balance between market freedom and being sufficiently prescriptive to achieve desired outcomes.

The evidence confirms that energy cannot be addressed or steered within a single spatial scale (Chlebna and Mattes, 2020) due to the configuration of the energy system (Becker and Naumann, 2017; Bridge, 2018). On the one hand, endogenous resistance to change driven by a desire to prolong the regime trajectory can stall the 'bottom up' development and embedding of new technology. Such resistance motivates actors to mobilise towards incumbent technology trajectory preservation, undertaking limited co-ordination activities and manifesting in a high level of path-adhering activities. On the other hand, where it is widely accepted that there is no possibility of reviving the existing industry, the analysis shows that a socio-technical option is being developed concurrently as the other diminishes, with the emergence of new actors and institutional arrangements (Chlebna and Mattes, 2020). This highlights that the likelihood of endogenous change is influenced by regional characteristics.

Where this thesis seeks to better understand how networks and place can enable the niches (Fuenfschilling and Truffer, 2014; Geels, 2011; Hansen and Coenen, 2015), it confirms the need to move beyond the TIS conceptualisation of 'networks of agents'

(Carlsson and Stanckiewicz, 1991, p.94) that are disengaged with spatialities (Bergek et al., 2008).

The analysis shows that the very heterogeneity of the spatialities within which actors that are part of the network are located can significantly impact the innovation process. The local network driven by regional actors is important to the early stages of technology development (Lundvall, 1988) but so too are non-local places when effective networks and social capital allow for the sharing of knowledge. In the case study, links with Orkney provides a channel of knowledge that helps MEP set up the appropriate infrastructure. In this way, it is possible to 'short-cut' difficulties by increasing intra-regional learning. However, the economic development status is perhaps critical, to understand how particular aspects might be compensated for. In many ways, the embedding of the new technology in the region has positive outcomes and these are considered next.

9.2.3 Embedding new technology

> RQ2: What role do actors and institutions play in embedding technology in places, and what effect do they have on innovation?

The findings confirm the hypothesis that embedding is a mechanism that can encourage transition in a region and show that this is especially important in less-developed regions or in those that suffer territorial mismatch. Institutional factors such as grant funding or the removal of barriers to investment provide strong market creation signals and bridge the gap between incumbent systems and pre-domesticating a technology. Importantly, aspects such as pre-prepared region-specific environmental and geographical data facilitate the utilisation of these natural resources by technology developers. As such, these steps can be undertaken by any of the regional actors and can ensure technology developers are aware of the region. However, further measures to facilitate embedding are necessary and can include the facilitation of knowledge networking, the generation of social capital, and supporting all stages of technology readiness.

In a less-developed region where there is a low number of actors, local support for new path creation and technology embedding can be created through the formation of networks and a drive toward co-location or clustering outcomes. Here, a focus on the development of knowledge networks and trust as opposed to facilitating 'business networking' is essential. In this case study MEW adopted this role. Where literature highlights the failure of 'top-down' cluster and development policy (Pike et al., 2007; Crescenzi and Rodriguez-Pose, 2011), the research presented here suggests that organic 'bottom-up' cluster principles that focus on gradually building relationships can better support technology embedding. In the case study the evidence shows how MEP is able to mobilise actors to connect, share knowledge, and engage with the industry. In a pre-commercialisation technology these factors have great potential to accelerate change.

The major finding of this research in the context of transition in a less-developed region is that in the absence of numerous actors, one with appropriate knowledge and leveraging ability can suffice. Goals of cluster-type mechanisms in order to support innovation and ultimately system transition by embedding the technology in a place are essential. This role does not necessarily have to be carried out by an institutional entrepreneur or separate body and could be undertaken by regional institutions that display institutional entrepreneurship attributes. Indeed, actors that contribute to the productive element of old technological systems can also support the innovative element of new systems (Markard and Truffer, 2008).

Yet the existing specialisations of a region direct the development of innovation (Köhler et al., 2019; Aarset and Jakobsen 2015) due to the skills within the existing industrial networks (Carvalho et al., 2012; Monstadt, 2007; Ornetzeder and Rohracher, 2013). As a result, the leadership of one actor must have a clear vision with extensive knowledge of the wide range of industry requirements. This is highlighted through the work of MEW that undertook activities to ensure the legitimation of the organisation by the WG. At the same time MEW were otherwise active in getting the industry to connect, create a network, apply for funding and raised the profile of the activities in the region in order that they were included in the Swansea Bay City Deal – outcomes that is likely to stand the subregion in good stead.

As conjectured, social capital is an effective tool in compensating for the economic and institutional deficiencies within a region to facilitate transition and technology embedding. Previously social capital has been recognised for its ability to support economic growth (Storper, 2005, 2013; Crescenzi and Gagliardi, 2015; OECD, 2001; Muringani et al, 2021), with the development of trust compensating for other shortcomings. Further, the presence of intermediaries and actors that undertake institutional entrepreneurship activities comes to the fore. However, it must be acknowledged that the replication of the social capital process in one region may not be possible in another (Malecki, 2012).

However, it could be suggested that where notions of market creation are essential (Geels, 2019), activities that are tailored to different technology readiness levels will better support embedding. The focus on technologies that are ready for market are evidenced in WG activities, but attention must be paid to the intermediate steps to commercialisation reducing the distance to pre-domestication of a technology. Indeed, questions around the desire and ability to pre-domesticate technologies that are further or closer to the market remain unresolved. The case study does show, however, that creation of technology testing and trial capacity alongside the minimisation of bureaucratic processes are key. In particular, understanding how to pragmatically approach consenting processes is an example of where actors that contribute to the regime and landscape should seek to innovate. Whilst in the case study these measures came too late for some individual ME technologies, the arrival and embedding of future generations of technology was secured. These new ways of working are market creation activities that are a strong signal to 'Radical Technology Actors' that governmental institutions are investing in the development of the corresponding TIS.

However, in a less-developed region where there are issues with institutional capacity and an absence of actors, there is the risk that much of the momentum rests on singular or a very small number of actors. This makes the creation of a new path more risk-laden and reflects increasing recognition in transition research of the fragility of this process (Chlebna and Mattes, 2020). This is in addition to the risks already incurred at a regional level due to the interdependencies on national and international developments (Jeling et al., 2019). This confirms the notion that endogenous change may be more challenging for less-developed regions, but there is mixed evidence around exogenous actors driving transition – the level of engagement between the CE and UK Government vary widely.

As the case of the MEIW shows, the research sought to explore the intersection between institutional thickness and persistence of path dependence (Dahlmann et al., 2017), and network building and its fragility (Chlebna and Mattes, 2020). Where the building of a network to support technology embedding has been shown to promote transition, it is also able to contribute to the drawdown of regional economic development benefits, which is the subject of research question 3.

9.2.4 Economic development alongside sustainability transition?

> RQ3. How do actors co-ordinate activities to pursue economic development benefits from innovation-driven sustainability transition?

The research has considered how new technology niches fare in a less-developed region, and whether there may be demands that are driven by this socio-economic system. The analysis suggests some principal findings – that in this socio-economic context, the technology trajectory that is most likely to maintain or enhance economic activity will take precedence, as there is an imperative for economic development. This confirms that pursuing both sustainable transition and economic development benefit from one type of innovation is a considerable challenge for the new technology trajectory. Echoing the findings of what promotes technology embedding, knowledge networks and the minimisation of transaction costs through social capital play an important role. However, it is in the pursuit of economic development benefits that the evidence suggests that governmental actors will seek to exert the greatest degree of influence.

Institutional goals that privilege economic growth and employment as an outcome of innovative technology may preclude the technologies that cannot immediately align with these criteria. This was evidenced in the case study and these residues of previous economic growth strategies, arising from lagging regional development, are significant inhibitors of transition. It could therefore be advanced that where a region has a strategy to engage with innovation to utilise natural resources, there is a need to temper short-term goals with the longer-term benefits of innovation that come from clustering and knowledge flow. In this way, there is greater opportunity for institutional goals and the new technology to align.

The two seemingly competing policy narratives of sustainability transition and economic growth suggest that when creating a market to pull a technology into the regime, there is a need to consider what technologies can support the complementary development of these two goals and provide targeted support. This said, these goals do not fit well with promoting nascent technology, and greater expectation management is perhaps necessary, particularly on the part of governmental actors. Achieving economic development in a less-developed region through a nascent technology is a significant challenge due to pressure to avoid 'risky' choices.

This gets to the heart of attempts to utilise novel energy technology development for regional economic development. Indeed, the extent of regional reconfiguration that is required to support technology for which there is limited knowledge, and success uncertain, could perhaps be considered too significant a task. Where regional development actors in a less-developed region have a greater necessity for job creation, this may overshadow the privileging of innovation support and low-carbon practices. Indeed, if the same nascent technology were developed elsewhere, it could be argued that the technology need only 'compete' with the technological needs of the regime. In a less-developed region, it is necessary to also align with the regional development goals of governmental actors. In this context there are two sets of institutional arrangement, each with their own technology filtering effects.

The analysis suggests that regional action should seek to remove the excess burdens faced by technology developers in order to promote technology embedding. At the same time, this framework will attract other developers to the region, and through the right embedding mechanisms, long-term economic development benefit can be locked into the region. Therefore, strategies for circumventing the described institutional deficiencies suggest a need to privilege regional knowledge sharing and voicing of shared goals early in the industry transition. In this respect, it is thought that the process of resource assessment stimulates conversation around RE and regional aims (De Laurentis and Pearson, 2020). This evidence confirms the assertion of transition literature of the need for shared goals (Elzen et al., 1996; Kemp et al., 1998) and adds the further insight of regional co-ordination.

The extensive efforts to minimise transaction costs observed in this research highlight that this is an important factor in securing embedding and providing more opportunity to pursue regional economic development benefits. The ability to minimise transaction costs, promote social capital and ultimately trust are activities that are within reach of most actors irrespective of financial capacity. However, it is essential for the actor that seeks to undertake these activities to also focus on legitimisation so that they become a trusted actor (Smith and Raven, 2012; Bergek et al., 2008).

It could therefore be concluded that in order to secure the maximum economic development benefits in a less-developed region it is necessary to combine market creation and technology support principles to break the likely dependency on previous economic growth strategies. These actions combined with activities to promote embedding of the new technology are then most likely to create economic development benefits.

9.3 Wider observations of transition

The research has evidenced that the spatial reach of the first stages of transition is limited and increases with technology development (Dewald and Fromhold-Eisebith, 2015; Chlebna and Mattes, 2020). The regional specificity of these activities is linked to some extent to the embeddedness of the technology, but expansion then leads to institutional adaptation that expands across scales (Karnøe and Garud, 2012). This was apparent in the activities of Pembrokeshire (NUTS3 region) that initiated local work in developing the nascent ME industry; these local initiatives then became institutionalised across Wales (NUTS1 region). Where it is supposed that competition increases between new and existing technologies (Chlebna and Mattes, 2020), the analysis shows that the incumbent technologies remain preferred whilst activity in the new technology trajectory takes place alongside. However, the ability to build relationships and connect with others is highlighted as crucial in the evidence (Chlebna and Mattes, 2020).

Where institutional pressure is exerted to encourage RETs, it is apparent that this umbrella term contains many technologies that have different support needs. As such, this ought to be reflected in the conceptualisation of transition where the development of technologies under the umbrella of ‘low-carbon’ or renewable are intertwined and impact one-another’s likely success. The evidence shows that residues of path dependency can make the acceptance of ‘bulk’ energy production more palatable, leading to the favouring of a few technologies.

There is a risk of transition activities focusing on a singular technology, such as the Swansea Bay Tidal Lagoon within the case study. It can therefore be concluded that there is perhaps a balance between market creation and innovation support, and in the absence of sufficient pressure in one area, activities can compensate in the other. If it were that there was insufficient innovation support activity and the institutions desired new technology, factors that are within the control of the region might include localised fiscal incentives and environmental mapping amongst others. This would increase the likelihood of institutional goals and the new technology aligning. Regional efforts can then be targeted towards growing recognition and momentum within the selected TIS (marine energy).

The case study establishes that in order to compensate for institutional deficiencies for new industries, it is necessary to move away from traditional types of institutional support. It has been shown that where regional policy can better address the approach to sustainability transition (Coenen et al., 2015; Bulkeley et al., 2010), a ‘one size fits all’ framework leaves much room for interpretation. If the desire is to ensure that a transition takes place, it is necessary to provide the type of dynamic support evidenced by some governmental actors (CE and NRW) that undertake steps to provide innovative solutions to support the ongoing development of the new technology trajectory. Much of these activities should focus on de risking processes and encouraging the long-term location and operation of a developer in the region.

Alongside institutional arrangements, the evidence shows that transition can be facilitated by a networked approach between actors. Actors are also motivated to join these networks due to an awareness of the benefits of knowledge sharing and reduced transaction costs. It must be noted, however, that the undertaking of transaction cost smoothing itself incurs expenses that may be compensated for through industry body membership or governmental subsidy. Importantly, these networks are a source of easily attainable knowledge that include localised detail - further contributing to embedding the technology.

From the research presented here, these networks have been shown to foster an environment where the sharing of failure is de-risked and transaction costs can be minimised. In order to encourage niche learning, this type of activity could be considered vital. Through maximising the impact of knowledge around failure it is possible to limit its reoccurrence, thereby accelerating nascent technology development. It can be concluded that regions can utilise social capital as an effective tool to compensate for the economic and institutional limitations experienced.

However, the evidence suggests that there is a danger in a less-developed region not of this actor making themselves an obligatory point of passage (Callon, 1986), but an over reliance on them by other actors due to the ability to economise on transaction costs and resources. This was evidenced in the case study and the theoretical framework developed outlined how industry and governmental actors routed relationships through one intermediary actor due to MEW’s ability to quickly access knowledge and network connections.

It can be concluded that the pivotal nature of a central intermediary role means that the actor best placed to serve would also need to have a longevity to its existence. As a result, should a government be serious about enabling a transition, it is best for them to undertake this role or appoint an actor to do so. This ultimately is more likely to secure long term economic development benefits. The danger in the case study is that should MEW cease to exist there is limited social capital and direct network relationships between government and industry actors.

Engaging with innovative technology engenders risk for actors, this includes supply chain organisations. The supply chain encounters risk in engaging with production processes where the ‘customer’ (developer) may have low resources, with the cost of learning at the early stages potentially not regained through producing a device at scale.

Evidence shows that supply chain organisations do engage with a raft of activities that are not core to their business in order to support nascent technology, doing so sometimes at no or low cost. In some instances, such as that of the Milford Haven Port Authority, the development activities of these technologies are disbanded, and potential future benefits are lost. A motivation to take these risks perhaps tie in to the less-developed and declining industrial context of the region – diversification is a necessity for supply chain companies that are losing the business of ‘Incremental Technology Actors’ but risk is incurred when engaging with ‘Radical Technology Actors’. Questions remain as to the approach in a region that is more economically developed.

Further, the evidence shows that the supply chain must also utilise absorptive capacity (Crevoisier and Jeannerat, 2009) to develop relationships with the developers. This would suggest that alongside fiscal support for developers, should regional or governmental actors seek to accelerate transition it seems necessary to support the upskilling of the supply chain. In this way, it would be possible for a less-developed region to make the available RE source more readily exploitable. As such, this may compensate for the difficulties experienced by the supply chain in supporting nascent technologies that are undergoing successive 'failures' in the niches.

Through adopting market creation measures that strengthen supply chain skills, any learning economies could also be retained in the region. Cultivating bilateral relationships between developer and supply chain may make a greater extent of embedding achievable. This would make it more possible to draw down economic development benefits and promote transition at the same time. When thinking of embedding regional benefits, this process would be beneficial as it could guard against developers utilising the knowledge capacity of the supply chain for the complex initial stages where there are limited economies, but not using these companies for the 'profitable' stage of manufacture or maintenance.

This said, with the nature of some of the technologies that will contribute to the energy revolution, the location of the natural resource will likely influence the location of developers and subsequent supply chain clustering. Those regions that have resource availability only possess an advantage if regional actors undertake the social and political action to make the resource exploitable; the 'technical potential' of RE resources outweigh the needs of Wales and the UK in energy terms. This outlines that spatial unevenness of RE deployment stems from both socio-economic factors and resource endowment (De Laurentis and Pearson, 2020) and enabling a transition depends on a balance of these factors.

9.4 Future Research

9.4.1 Testing of theoretical framework developed in other contexts

The application and investigation of the theoretical framework in different contexts would support the understanding of how representative the findings with respect to relationships and knowledge sharing are. In particular, it will be important to understand whether it is a common characteristic of transition in a less-developed region to be dependent on one actor.

Were the investigation to be carried out in the context of a larger industry than that of the MEIW, a social network analysis would be an appropriate tool to track connections. A Social Network Analysis explores how agents connect and the reasons for doing so, helping ascertain the structure of the network and how knowledge flows. At the time of field research, the distinctive qualities of the nascent MEIW networks meant that a Social Network Analysis approach was not adopted, but this approach may well have value in an industry where there are numerous nodes. Through utilising a Social Network Analysis, it is possible to understand the centrality of actors and nodes, providing detailed insight into the network attributes that support transition in a less-developed region.

Where a larger network is surveyed, a smaller number of actors could be selected for interview to generate the Q Method statements that are then issued to the wider network. Indeed, an extension of the research analysed in this thesis would be the issuing of the Q Method throughout the network of MEW to introduce ‘outside’ views from those that are not embedded in Wales. Further, this method could be employed in other regions that are less-developed to establish where there are collective opinions on what is most important in a less-developed region. This would require some tailoring of statements but would further support the generalisability of the findings within this thesis.

9.4.2 Path creation in a less-developed region

The nature of sustainability transition demands the reconfiguration of many systems. Scholars have started to analyse the role of institutional agency in shaping industrial path creation (Grillitsch and Sotarauta, 2019; Isaksen et al., 2018; Sotarauta and Suvinen, 2018; Dawley, 2014). This institutional agency embraces the idea of path creation as a process of mindful deviation not only from technological and knowledge artefacts, but also from the relevant institutional structures (Garud and Karnøe, 2001). This case study has convincingly shown that distributed system building processes, (policy interventions, institutional entrepreneurship, strategic resource mobilization), play a key role for path development - largely on par with related knowledge and skill sets (Carvalho and Vale, 2018; Binz et al., 2016b; Dawley, 2014; Garud et al., 2010; Garud and Karnoe, 2003).

An observation emerging from this research is that the socio-economic status of the region impacts openness to change. Two differing subregional approaches have been evidenced, and this research contributes to the conceptualisation of regional transition paths to sustainability (Strambach and Pflitsch, 2018) which is insufficiently explained by the niche-regime dichotomy (Späth and Rohracher, 2015; Geels et al., 2016). The place politics of energy and economy is shown to help maintain regimes where there is the possibility of reviving the incumbent industry. This raises interesting questions that warrant further research as to beliefs about the mutability and substitutability of multiple dimensions of a socio-economic system – income, economic identity, cultural identity and how these factors play into the prospects for 'mindful deviation' (Garud and Karnøe, 2001; Simmie, 2012). This shows how place is intrinsic to the dynamics of transition. Extension of this research would contribute to the better conceptualisation of institutions and the likelihood of institutional innovation with transition aims (Strambach and Pflitsch, 2020).

9.4.3 Intermediaries and institutional entrepreneurship activities for transition

The research has highlighted that increased actor responsibility for change comes as a result of institutional deficiencies. In the absence of numerous actors and supportive institutional framework, there is the requirement of a responsive actor that is prepared to evolve. This is in contrast to theorising that those regions with a large number of actors will better negotiate the innovation space. It can therefore be asserted that it is not the nature of the actor or its organisation that matters, but its scope to act as an intermediary, and to focus on the relationship building and knowledge networking. Arguably, these activities could be undertaken by private or public organisations to identify industry needs and intermediate the linking of actors to form networks of knowledge. The benefit of doing so is to shortcut social capital development and encourage collaboration.

However, it remains a possibility that these co-ordinated activities and intermediation are a unique aspect of the studied region; indeed, these endogenous activities did not take place in both NUTS3 regions. As such, the exploration of transition in less developed or institutionally thin regions will add further to the growing literature on the role of actors and institutional entrepreneurship activities in transition.

Further in this vein, research should be conducted into the evolution of the actors within Wales that contribute to industry development and transition as ME progresses towards commercialisation. The literature on intermediaries within transition is growing, where research such as Kivimaa et al. (2019b) evaluates the work of intermediaries through the different phases of transition. The study of Wales has evidenced the evolution of an intermediary into an institutional entrepreneur in response to regional characteristics where economic development is sought from a nascent technology. It is possible that the distinction between these actor concepts may become increasingly muddied as transition intermediaries are increasingly assessed for their ability to leverage change.

9.5 The future in Wales

9.5.1 The implications of Brexit

The evidence has highlighted the instrumental role of European funding both in the development of the MEIW and the locking in of economic development benefits through the criteria attached to these funds. With the UK’s exit from the European Union there are inevitable questions about the development of the industry in the absence of these funds. It can be concluded that the role played by these funds could be adopted by another actor, indeed other governmental bodies could provide the same terms and criteria for fund utilisation. However, the yet unanswered aspect is whether ME development would be factored a priority in a region that has many other social and economic issues that need addressing. In particular, the pre-commercialisation nature of the industry with limited evidence of success makes it likely that these funds would be prioritised elsewhere.

However, the evidence highlights that many of these developers have private sources of funding, and in the absence of grant funding it could mean a faster narrowing of the niche with only those technologies that are likely to succeed and have the financial capacity to do so will continue. It could be argued that this comes at too early a stage for ME technology but there is evidence of several developers that are now passing to the demonstration and trial phase in Wales. It can therefore be concluded that the implications of Brexit will be more severe for those technology developers that are yet to reach a stage where it is more possible to seek out private finance than those who are sufficiently progressed to demonstrate the effectiveness of their design.

9.5.2 Contribution of ME technologies to transition in Wales

Uniquely, this thesis has sought to understand the pathway of a niche, pre-commercialisation technology that is navigating a trajectory that currently lies between success and failure. Mostly, transition studies explore those technologies that have been concluded to be a success or a failure. The importance of this research even were marine energy not to become a success lies in understanding the agency of actors that seek to build momentum for a technology and how this contributes to the technology's trajectory. Studying a transition in action allows the opportunity to capture the agentic motivations of actors, the outcomes of events as they unfold, and contributes deeper learning to the minutiae of this process that can be lost when investigations taken place ex-post. However, it is appropriate to seek to draw this thesis to a close with a hypothesis of the likely outcome of the MEIW based on the evidence gathered and the theory that is available.

It is important to note thatthe stasis of ME between success and failure is similar globally, with efforts to both innovate a niche design and contribute to the overall energy transition movement in a timely manner. Arguably, there are some factors that show that ME is enjoying more success in Wales than other places. Importantly, it can be concluded that embedding the technology in a region is advantageous, where literature tells us that there is a 10-year gap between tidal stream and wave technology (ORE Catapult, 2018), the technologies that are operating in Welsh waters are at a commensurate level of progress.

The key determinant of success for the ME is the alignment of temporal aspects - the narrative has shown that there are many technology trajectories that are likely to intersect with the ME trajectory both in terms of innovation and sustainability transition. The cost of electricity produced by ME is currently high, it will be necessary to reduce this cost swiftly to ensure that ME becomes part of the portfolio of RETs that contribute to energy security and sovereignty. This development needs to happen at both the Wales and global scale to ensure uptake within the UK electricity system.

Whatever happens in this broader context, there remains the opportunity for ME within island communities and nations, where the price of electricity is pitched against that of imported fuel for generators and small-scale electricity system. Ultimately, with a focus on innovation and not transition at a Wales or UK-scale, it is possible for Wales to enjoy some of the success of this market. As highlighted by the evidence, Wales has an advantage of deep-water ports,a cluster of engineers with innovative design talent, advanced manufacturing skills to create the devices, and a knowledge not only of the technical but also the social skills needed to support the development of a niche technology. If the embedding of these features is pursued, this creates a new legacy for the region.

The evidence suggests that the ME sector and its transition will continue in Wales, as discussed in Section 8.3.5 there are many factors that suggest a transition is taking place.

This includes the articulation of visions by actors including WG, MEW and CE, the building of social networks, and the ongoing dynamics of learning processes. The likely areas of opportunity to Wales are the extensive natural resource, a strong supply chain with industrial competency for heavy industry steel products that work in a marine environment, and declining industry that provides an impetus for change. However, the biggest challenge to the industry in Wales is the pre-commercialisation status of ME technologies and its location within a less-developed region. The research points to activities that have been undertaken in this context that have created areas of precarity; particularly the focus on a small number of high-cost technologies that generate RE at scale and sit in the intersection with larger-scale employment as a precursor to growth.

Much like the focus on a small number of technologies, the dependence on a small number of actors to undertake intermediary and institutional entrepreneurship activities emerge as an outcome of the lower level of economic development in the region. This presents a further risk to the unfolding transition in Wales. It may be that in order to effect change for nascent technologies that fit into a new growth paradigm it may be a necessary step to undertake extensive institutional work. Technology developers are shown to have limited capacity to do so, and in less-developed regions the prioritisation of growth is evidenced. It may be, that in the context of a less-developed region these behaviours are observed but not in others. However, to capitalise on this opportunity, it is necessary for actors in Wales to disaggregate the opportunities that are offered by innovation from those offered by transition.

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Appendix A – Anonymised coding

Actor Type	Selection reason
Technology Developers (TD)	
TD1	Wave developer
TD2	Tidal developer
TD3	Tidal developer
TD4 (Disbanded TD)	Tidal developer
TD5	Wave developer
Supply Chain (SC)	
SC1	Deployment capabilities
SC2	Legal capabilities
SC3	Fabrication capabilities
SC4	Knowledge capabilities
SC5	Knowledge capabilities
SC6	Knowledge capabilities
SC7	Legal capabilities
SC8	Knowledge capabilities
SC9	Knowledge capabilities
SC10	Deployment capabilities
SC11	Fabrication capabilities
SC12	Fabrication capabilities
Government (GV)	
GV1	National Government
GV2	Regional Government
GV3	Sub-regional Government

Appendix B – Generic interview schedule

The following interview is part of the fieldwork for an ESRC funded PhD Project that seeks to explore how developers of technology, policy makers and other actors in the marine industry contribute to the uptake of a technology and encourage system transition in the energy field/market. It is important to note that the industry is to be used as a case study to understand sustainable transition. This means that the interview is not asking for commercially sensitive data. The data gathered through this interview will be anonymised, and you have the right to veto or anonymise any of the data that you do share. The data will be used to compose a case study and to create a 'network map' of the relationships between actors in Wales, utilising aggregate descriptor groups, thereby providing anonymity for companies that may be named during this interview or subsequent survey. Your participation in this interview is entirely voluntary and the interview can come to an end at any point that suits yourself. Are you still happy to participate in the interview? I would like to record this interview, is that agreeable?

Interview Schedule Generic:

- If you would like to begin by telling me a little about the work of X?

- What activities are important for your day-today operations?

- What are the main difficulties you encounter in your operations?

- What are the main ways in which you establish connections with organisations?

- Are there particular individuals/organisations who you work with on a regular basis? In what kind of capacity? How did you establish this contact?

- In particular, thinking about the supply chain, how do you identify organisations with the required skills set?

- What type of events do you attend? Do you attend looking for business contacts, information or collaborators?

- Do you have any involvement with Marine Energy Pembrokeshire? Milford Haven Port Authority? Crown Estate? Natural Resources Wales? Welsh Government? What is the benefit to your organisation?

- Have you received any government funding, what was your experience?

- Do you have involvement with any of the Universities or education institutions in Wales?

Appendix – Q statements

Q Statements in order presented to the participants:

1. Previous experience in other industries (including other energy) influences the work that you do in marine energy
2. A University has played an important part in your operations
3. It is difficult to source all supply chain needs in Wales
4. It can be difficult to balance R&D/new activities with business management
5. Location in an area with several marine energy related companies allows you to work more effectively
6. It is important for the supply chain to understand the technology that is being created so that it can support its design
7. You can learn from marine energy companies that have failed
8. It is important to keep knowledge within the industry, and employing people from failed companies is a useful way to do this
9. Marine Energy Pembrokeshire/Marine Energy Wales is influential for industry development in Wales
10. The ability to tap in to ready-prepared geographical and environmental data would be beneficial
11. Learning about the experiences of Scotland and other regions is beneficial to developing your marine energy activities in Wales
12. Supply chain companies sharing the lessons they have learnt has positively affected your organisation
13. You prefer to work with businesses that have a similar culture/way of working as yourselves
14. Industry-wide meetings allow you to effectively gain contacts, knowledge, and resolve queries

15. You undertake collaboration exercises to gain new knowledge and strengthen relationships

16. Having a network of contacts means you can easily access information that you need

17. Non-statutory bodies are influential to industry development in Wales

18. Demonstration zones will be influential to marine energy industry development in Wales

19. Companies based in the same geographical area are important to your business

20. A lack of funding and financial support curtails marine energy industry development

21. There is a skills shortage in Wales to complete the tasks demanded of the supply chain

22. Welsh Government energy policy sufficiently supports the development of marine energy in Wales

23. European funding guidelines can be restrictive for business operations

24. Local government or other statutory agents should facilitate business match-making

Arising themes:

- Brexit
- Social Capital
- Decline in other industries
- Funding

Market creation broad themes:

- Industry Development
- Embedding technology
- Encouraging change
- Governance
- Knowledge flow/dissemination
- Technology Development
- Interaction with Global
- Intermediaries

Market creation specific:

1st level	2nd Level	3rd level
EU	Policy	Positive
		Negative
	Institution	WEFO
UK	Policy	Positive
		Negative
	Institution	Crown estate
		ORJIP

Wales	Policy	Positive
		Negative
	Institution	Welsh Govt
		Regional Govt
		NRW

Innovation support broad themes:

- Industry Development
- Embedding technology
- Encouraging change
- Governance
- Knowledge flow/dissemination
- Technology Development
- Interaction with Global
- Intermediaries

Innovation support specific:

1st level	2nd Level
Marine Energy Pembrokeshire	Technology progress
	Industry progress
	Knowledge flow/dissemination
	Social capital development
Marine Energy Wales	Technology progress
	Industry progress
	Knowledge flow/dissemination
	Social capital development
	Technology progress

1st level	2nd Level
Anglesey Energy Island	Industry progress
	Knowledge flow/dissemination
	Social capital development

Technology embedding broad themes:

- Industry Development
- Embedding technology
- Encouraging change
- Governance
- Knowledge flow/dissemination
- Technology Development
- Interaction with Global
- Intermediaries

Technology embedding specific:

1st level	2nd Level
Developers	Technology progress
	Industry progress
	Knowledge flow/dissemination
	Working culture
Supply chain	Technology progress
	Industry progress
	Knowledge flow/dissemination
	Working culture

1st level	2nd Level
Intermediaries	Technology progress
	Industry progress
	Knowledge flow/dissemination
	Working culture

- Industry Development
- Technology Development
- Embedding technology
- Encouraging change
- Governance
- Knowledge flow/dissemination
- Interaction with Global
- Goals
- Intermediaries
- Growth
- Influence
- Other industries

Appendix F – Policies analysed

Year	Title	Government
2019	Prosperity for All: A Low Carbon Wales	Wales
2016	Hendry Review	UK
2015	Wave and Tidal Energy in the UK: Capitalising on Capability	UK
2014	Marine energy technology roadmap 2014	UK
2014	Wave and Tidal Enabling Actions Report	UK
2014	Maximising the Value of Marine Energy to the UK	UK
2013	UK renewable energy roadmap (update)	UK
2012	UK renewable energy roadmap (update)	UK
2012	Technology innovation needs assessment (TINA) marine	UK
2012	UK Wave and Tidal Key Resource Areas	UK
2012c	Energy Wales: A Low Carbon Transition	Wales
2012b	Energy Policy and Planning in Wales	Wales
2012a	Marine Energy Infrastructure Study	Wales
2011	UK renewable energy roadmap	UK
2011	Marine Renewable Energy Strategic Framework	Wales
2010b	Marine energy technology roadmap	UK
2010a	Marine energy action plan 2010	UK
2010	A Low Carbon Revolution - The WAG Energy Policy Statement	Wales
2009b	The UK renewable energy strategy	UK
2009a	The UK low carbon transition plan: national strategy for climate & energy	UK
2009	Capturing the potential - A green jobs strategy for Wales	Wales