Literature Review of Industrial Policy Options for Renewable Energy

Task 2.1 of WP4 from the MERiFIC Project

A report prepared as part of the MERiFIC Project
"Marine Energy in Far Peripheral and Island Communities"

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1 Introduction

1.1 The MERiFIC Project

MERiFIC is an EU project linking Cornwall and Finistère through the ERDF INTERREG IVa France (Manche) England programme. The project seeks to advance the adoption of marine energy in Cornwall and Finistère, with particular focus on the island communities of the Parc naturel marin d'Iroise and the Isles of Scilly. Project partners include Cornwall Council, University of Exeter, University of Plymouth and Cornwall Marine Network from the UK, and Conseil général du Finistère, Pôle Mer Bretagne, Technôpole Brest Iroise, IFREMER and Bretagne Développement Innovation from France.

MERiFIC was launched on 13th September at the National Maritime Museum Cornwall and runs until June 2014. During this time, the partners aim to

Develop and share a common understanding of existing marine energy resource assessment techniques and terminology;

Identify significant marine energy resource 'hot spots' across the common area, focussing on the island communities of the Isles of Scilly and Parc naturel marin d'Iroise;

Define infrastructure issues and requirements for the deployment of marine energy technologies between island and mainland communities;

Identify, share and implement best practice policies to encourage and support the deployment of marine renewables;

Identify best practice case studies and opportunities for businesses across the two regions to participate in supply chains for the marine energy sector;

Share best practices and trial new methods of stakeholder engagement, in order to secure wider understanding and acceptance of the marine renewables agenda;

Develop and deliver a range of case studies, tool kits and resources that will assist other regions.

1.2 This Report

The development of national and regional new renewable energy industries is unlikely to come about simply from policies which drive growth in deployment alone. The purpose of this report is to provide an overview of policy options that are available to both support the growth of renewable energy sectors (inclusive of supply chains) and specifically the regional marine renewable energy sector, as an alternative to simply providing expanded capacity.

This will inform the later stakeholder consultations within the MERIFIC Policy work package as well as serving as a relevant consolidation of industrial development of RE and the options available specific to growing and exploiting marine renewable energy as a source of economic growth as a well as a sustainable generating option.

This document provides a comprehensive analysis of existing literature concerning the industrial development of renewables and represents a distillation of the most current theory

1.3 Motivations for an Industrial Policy for Renewa ble Energy

Arguments for the supporting of renewable energy technologies are primarily rooted in our current understanding - and desire to mitigate, the many negative predicted effects of climate change. Although this report will not re-cover already well explored territory; the consequences of a 'business as usual' scenario for greenhouse gas (GHG) emissions are clearly seen as having grave environmental, social and economic consequences both within the UK and globally. These adverse environmental effects include an increased likelihood of extreme weather patterns, rising sea level, droughts and various other changes in expected normal weather patterns (IPCC, 2007). Although the worst environmental impacts are not expected in the UK, there will certainly be much adaptation required and the UK government commissioned Stern Report predicted a mean drop in UK per-capita consumption of 14.4% by 2050 under this scenario (Stern, 2007).

As well as environmental reasons, there are clearly human social factors for wanting to change our energy system. The most notable of these is perhaps the desire for energy security. Although there are differing definitions as to what energy security entails; long term stability, durability of the system, robustness to long term change and resilience to acute system shocks are all factors (Mitchell, 2012). Nationally, energy security can be thought of as the ability to ensure that fuel and technology supplies are protected or mitigated against exogenous factors to the state such as production shocks. Finally, energy security can be thought of in terms of social equality within a society covering affordability of energy and fuel poverty within poorer communities.

Unfortunately, in a purely laissez-faire world, the natural economics of incumbent technologies are more financially attractive than most renewable energies due to several important factors: Firstly, the negative externalities of current status-quo combustion generation, (i.e. coal, gas and oil) which emit GHGs, pollutant oxides (SOx & NOx) and particulate matter are hard to quantify and are only just starting to become successfully commoditised through carbon pricing mechanisms. Secondly, the infrastructural and operational legacy of these systems favours their continued use as wider changes in grid and system operation will be required for renewable technologies to break through, (e.g. combustion technologies use centralised generation plant which fits in with the existing transmission systems and provide flexible demand responsive generation). This case is somewhat different for nuclear power which offers benefits in terms of baseload, however there are still incumbent technology lock-in/lock-out factors (such as the requirement for nuclear munitions) which support the nuclear industry. Thirdly, most existing combustion technologies have had a long (and often heavily subsidised) period of both technology diffusion and incremental (as well as at times radical) innovation in which to bring manufacturing and generation costs down (Jacobsson and Bergek, 2004). Finally, other market failures such as risk aversion (as a result of lack of ability to obtain information on the risks of investment), higher transaction costs and a simple lack of access to appropriate sizes of capital, all act against the development and deployment of renewable energies (UK Government, 2011).

For these reasons, economic policies for renewable energy must acknowledge that a imperfect market structure exists within the energy industry and that there is a requirement for policy intervention if our wider environmental and social needs are to be met. In addition to this requirement for change from the incumbent landscape, there are several strong reasons (specifically within the UK and France) why marine renewable energy technologies are advantageous within the overall energy portfolio:

Firstly, there is a large resource potential for ma

This presents strong indicators to policy makers' effective innovation R&D activity spending can occur (Chang and Chen, 2003).

2.1.2g Technology Innovation Systems

Technological Innovation Systems (TISs) first appeared as a form of analysis in 1991 when Carlsson and Stankiewicz published 'On the nature, function and composition of technological systems' (Carlsson and Stankiewicz, 1991). In this paper they suggested that the development potential of countries was related to the number and success of technological innovation systems within it, while acknowledging that these systems may not be confined to either national or other geographic borders. They defined Technological Innovation Systems as:

> "A dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology" (Carlsson and Stankiewicz, 1991)

Although they did not give an operational method for analysis of such systems, their work identified key attributes that were suggested as being:

- Economic competence: A company's ability to develop and exploit new opportunities;
- Clustering of resources: The perceived necessity for a clustering of industries that Carlsson argued has been historically required for innovation to occur;
- Institutional infrastructure: The need to reduce 'social uncertainty' and mitigate potential conflicts through the introduction and enforcement of institutions.

The key distinguishing features that this early formation of TIS held from National Systems of Innovation, were the lack of geographical borders and their specific focus on the micro and meso-economic factors (such as the individual entrepreneur, firm, their competencies and networks) that are central to their formation. Indeed, when a national boundary layer is used, the technological innovation system identified by Carlsson did in fact have many aspects in common with its predecessor, the NIS as outlined by Nelson, (Carlsson and Stankiewicz, 1995, Nelson, 1992, Nelson, 1988)

In 2000, Jacobsson & Johnson built on this work by creating the first rough work on a framework of analysis (Jacobsson and Johnson, 2000). In this, they identified some of the key structural components (or elements as they described them then) of the technological innovation systems that they argued needed to be both separated and identified were important occurrences within a TIS to be understood. These elements were: Actors, networks and institutions. Without defining what actions these elements were required to carry out (as was later the case) Jacobsson and Johnson identified some of the factors that they argued led to failure of adoption and diffusion for specific technologies within a system. These included functions such as 'poor connectivity', 'local search processes' and 'legislative failure'.

Liu and White, referring to Carlsson’s 1995 book, came to a similar conclusion that the

Bergek's formalised definition of technological innovation systems was detailed within her 2008 paper, Analysing the functional dynamics of technological innovation systems: A scheme of analysis (Bergek *et al.*, 2008a). In this she modifies and incorporates functionalities into a scheme of analysis outlined by three years earlier by Masters students Gustav Oltander and Eugenia Perez (Oltander and Perez, 2005). This scheme of analysis places the importance and contribution of functionalities within an analytical framework for assessing the overall health of the system in a logical 'step-by-step' approach as shown in Figure 4 below:

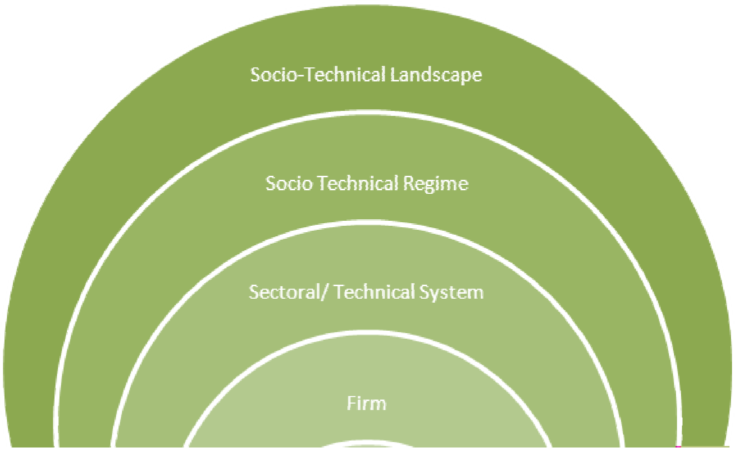
[1]

Figure 4: Scheme of System Analysis Adapted by Bergek (Bergek et al., 2008a)

In this model of analysis, actors, networks and institutions (laws and regulations) are identified. Their contribution towards the various achieved functional patterns is then assessed on a function-by-function basis. From here, bottlenecks/reverse salients (i.e. blocking the full development or operation of a function) can be identified and policies put in place to rectify this.

2.1.2h Conclusive Remarks about Innovation Systems

Arguably, one reason why innovation literature exists on so many systemic levels is because they all share some level of validity (and in many cases, overlaps) when assessing the influencing factors upon innovation from different perspectives. Thus, a synthesis of their frameworks and complementarities is beneficial. As understanding of the relationship between different system stakeholders, their knowledge inputs on innovation and their effects on that system have grown, so too has the overall systemic boundaries that are used to understand the process. Figure 5 below places innovation within the context of differing spheres of influence as amalgamated from the above innovation systems literature.



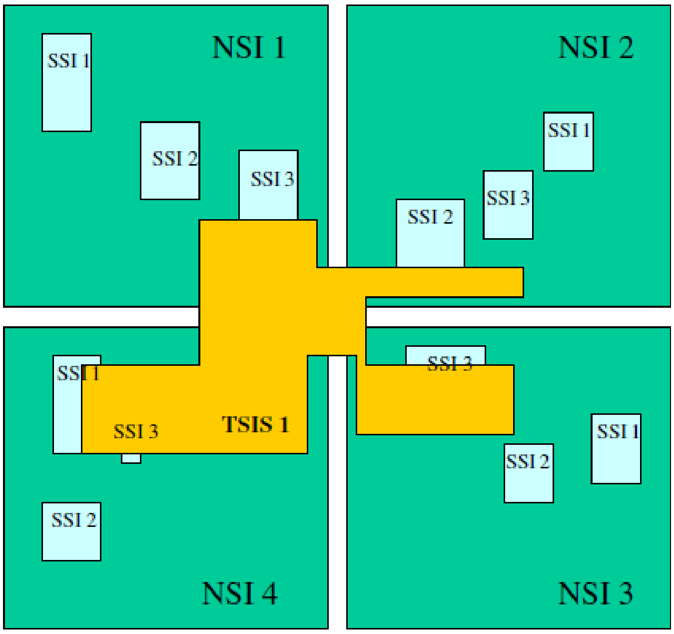


Figure 6: Hekkert's Boundary relations between National, Sectoral, and Technology Specific Innovation Systems

2.1.3 Transitions

2.1.3a Transition Management and Strategic Niche Management

Within emerging systems of innovation, there is an acceptance that the rate of growth of the system may be slow due to high levels of uncertainty (and thus low legitimacy) in the overall technological trajectory and the associated high levels of financial risks for investment. This may be exacerbated in renewable energy systems where incumbent technologies (or the incumbent regime rather) needs overcoming and (in the case of fossil fuels) has a natural economic advantage due to (among other things) the natural externality of GHG emission costs, while sustainable technologies rely heavily on the (often fickle) support of political will.

Working from Geels' multi-layered perspective of niches (See section 3.2.2b above) as a model of transition management, Raven distinguishes the following aspects (Geels, 2004, Geels, 2005, Witkamp et al., 2011, Raven et al., 2010):

- On influence, Landscapes (by definition) are external to any single actors influence and regimes are usually very stable, 'status-quo' fields that usually have strong inertial resistance to change. Niches by contrast are usually under-developed and have little structure however the forming of institutional norms is still 'up-for grabs' (by prime movers and other early key stakeholders).
- Stakeholders will have different perspectives on what they believe to be different fields (niches/regimes and landscapes) therefore analysis is not ontological (i.e. the models of analysis are very much a relative construct of the researcher).

- Finally, successful transitions tended to occur through ‘fruitful coupling’ between all the different levels

When experimenting or applying policy instruments to encourage transition shifts, these fall into 3 broad notions: Deepening (activities that aim at learning as much as possible about the niche from an experiment or instrument), broadening (activities aimed at extending the application of an experiment or instrument to a different context within the niche), and scaling up, (activities aimed at bringing the experiment or instrument into a higher ‘level’ (i.e. the regime))(Raven et al., 2010).

Separate to this, Raven identifies strategic niche management (SNM) as the focus of developing the niche layer of a system into a more developed stage (e.g. developing wave energy technology into the mainstream energy market). Here, Raven identifies three processes that tend to play an important aspect on niche success, these are (Raven et al., 2010):

- The shaping of expectations which are positive when there is joint agreement within the niche over future expectations and these are borne out from tangible results (i.e. similar to the concepts of *search heuristics* or *influence upon the direction of search* (Dosi, 1993, Bergek *et al.*, 2008a))
- The building of social networks coming from different field and disciplines, (supporting Burt’s theory of *structural holes* discussed in the Structural Holes and Theories of Network Closure section below as well as Low and Abrahamson’s development of successful industries (Burt, 1992, Low and Abrahamson, 1997)).
- A good, (broad yet flexible) learning process exists within the niche aligning the technical options with social ones.

Smith focuses heavily in his work on the locus and agency of changes for systems of innovation (or transition management). Noting that drivers for regime change (where a ‘regime’ here is defined as the dynamic activities of a system) can come from both internal and external drivers as well as through intended or unintended (proactive or reactive) transition, Smith coins the phrase ‘quasi-evolutionary’ to describe the way in which these processes are coupled. He goes on to create a conceptual mapping of this process shown in Figure 7 below:

Figure 7: Smith's transition contexts as a function of degree of coordination to selection pressures and the locus of adaptive resources (Smith et al., 2005).

With this conceptual map, both normative and positive forms of analysis are available to system governors. In the first, analysts can perform an active role in managing the system through 'levers' of change which can be used to steer the system towards a more desirable overall direction of progression. These levers include such things as the building of adaptive capacity within the regime or the articulation of the selection process (whether externally or internally sourced). The second, "analytical" mode (which is similar to the concept of 'positive' economics), in which analysts can deduce a passive understanding of the transition of a regime, taking the governing process as itself being embedded within the regime (Smith et al., 2005).

2.1.3b Industrial Development Stages

Industrial development of renewable technologies often faces a 'chicken and egg' dilemma whereby technologies only begin to become commercially competitive once a large amount of diffusion (and the associated learning, cost reductions and economics of scale) has been realised. Unfortunately, this diffusion very rarely occurs naturally without the technology already having commercial competitiveness over competing technologies.

Looking at early work on diffusion, one of most famous early studies (and the coining of the term 'diffusion' when applied to innovation) was published in 1943 by Ryan and Gross (Ryan and Gross, 1943). They investigated the diffusion of hybrid corn among two Iowa communities from 1928 to 1941 and sampled over 250 respondents. They found that the process of diffusion for a superior form of hybrid corn depended heavily upon not only agri-business sales men, (who managed to persuade early adopters) but more so, on the informal networks of communication between farmers who had been using the corn and those that had not. In other words, it relied heavily upon trust and what is today thought of as ‘social capital’ (Coleman, 1988). Although this research was not unique in looking at diffusion, it was a milestone for the formalisation of the theories and study of diffusion theory which was still a diverse discipline falling under the academic domains of rural sociology, marketing, education and anthropology among others at that time (Rogers, 2003).

It was not until Rogers’ (now re-published) 1962 book, “Diffusion of Innovations” (Rogers, 2003) that diffusion theory was finally bought under one ‘umbrella’. Bringing together the body of research done by various scholars within differing disciplines over the 40s and 50s on the process in which innovation and ideas spread throughout a community of adopters. In this book, Rogers highlighted the commonality of findings that had been seen in previous works on diffusion such as the regular ‘S-curve’ of diffusion and the fact that early adopters (innovators) had higher socioeconomic status than later adopters (laggards) (Rogers, 2003). This idea was later formalised to produce what is now known as the Bass model which presented the first mathematical model for the estimation of innovation diffusion within a community over time (Bass, 1969).

Specific to renewable technology diffusion one notable paper was Foxon et al.’s 2005 paper on UK innovation systems for new and renewable energy technologies: drivers, barriers and systems failures (Foxon et al., 2005). Here, Foxon modelled the technology diffusion process through stages of technology maturity in which technologies pass rather than time being in direct relation to diffusion of new innovation. Foxon realised that market penetration of RE technology was reliant upon the level of technology maturity (and to some degree vice-versa since technology ‘push’ was required to achieve deployment that would in turn lead to increased technology learning).

Foxon’s levels of technology maturity are described as:

- R&D: The basic principles of the technology are understood and no diffusion has occurred. There is still a great level of scope for radical levels of innovation.
- Demonstration: Attempts to design and build the technology are or have been made however the technology has not been proven to key early stage investors (‘Innovators’ (Rogers, 2003) or ‘Movers’ (Low and Abrahamson, 1997)).
- Pre-commercial: In which the technology has been proved however the economic scalability of the technology and its relationship to the existing status-quo is still uncertain. This period includes the ‘valley of death’ stage, in which a company is at high risk due to the high need for capital required for investment in plant and operations yet the low level of returns from the slow initial stages of diffusion.
- Supported commercial: This is the stage in which the technology is most likely to be driven by revenue based support, (market pull) and is effectively ‘competing’ within the status-quo arena, (similar to Geels’ regime described in section 3.1.1b below, (Geels, 2004)).
- Commercial: The final stage of maturity in which the technology is considered to be un-supported, (or in as much of a sense as all othe

Bounded Rationality:

Bounded rationality is a pervasive term within evolutionary economics that refers to the concept that: 'real life decision problems are too complicated to comprehend and therefore firms cannot maximize over the set of all conceivable alternatives.' (Nelson and Winter, 1982). As a result of this, firms act upon simplified understandings and models of the market. Resources can be deployed to increase a firms understanding of the market however there will always be limitations on the rationality of choices made which will make the firm, (and collectively the sector) perform at sub-optimal level. The term 'bounded rationality' was first used by Herbert Simon in his book; Models of Man, (Simon later became a founding father of artificial intelligence and won a Nobel Prize for his work in economic decision making)

Group Think & 'Not Invented Here':

These terms are closely connected and relate to a company's internal notions of itself. Group think is a phenomenon wherein people's interdependencies and expectations of their peers limits their field of inquiry when undertaking innovative activity. This behaviour has also been sighted in cluster theory where companies become confined by their own sense of collective operational behaviour.

'Not Invented Here' syndrome is one in which firms develop over time a routine of both operation and search criteria within their innovation procedure which causes them to preclude certain possible combinations or indeed not see the value in innovations which may not have a value to their existing operations.

Technology Lock-In/Path Dependency:

Technology lock-in and path dependency are similar concepts that relate to the internal decision making process which companies undertake. Once a company decides upon a direction of innovative activity, it must allocate resources such as staff and funding towards that goal and in doing so pays an *opportunity cost*, foregoing other directions of research. As these resources get further allocated towards the initial innovative goal, the availability of alternative options becomes narrower and narrower. Theoretically, if a company had unlimited resources it would not suffer from technology lock-in as it could peruse all options available to it at any given time.

Incumbent Resistance/Social Inertia:

These last aspects are not in fact related to the characteristics of the innovation as such but rather, the system and societies acceptance of the innovation. Incumbent resistance can stifle any change to an industry sector through control of supply and distribution lines, patent freezing, lobbying for prohibitive legislation and a plethora of other manoeuvres. Likewise, even without an incumbent industry to work against, social lack of knowledge, understanding or trust can cause an innovation to fail. Social resistance is usually a prevalent phenomenon where the utility value of the innovation may not be explicitly, obvious such as with renewable energy.

2.2 Renewable Case Studies

As with other energy systems theory text, there are a multitude of academics who have built upon case studies of renewable energy within a specific country or region focussing on a particular technology to highlight policy failings or successes and in many cases drawing generalised conclusions for what may work in future policy scenarios within a similar contexts. Examples of this come from industries such as the (predominantly Danish) wind turbine, (Karnøe, 1990, Johnson and Jacobsson, 1998, Harborne and Hendry, 2009, Jørgensen, 1995) solar, (Shum and Watanabe, 2009) and biomass industry (Negro, 2007) as well as a wealth of geographically focused studies that focus on the mechanisms as well as historical processes of change and policy framework rather than on any specific technology (Connor, 2003, Mitchell and Connor, 2004, Lund, 2006, Foxon and Pearson, 2007, Watson, 2008).

The collective body of work looking at renewable energy policy through case studies is clearly extensive and could be conceptually subdivided and presented in many ways; by technology groups, geographic size or location, political environment, maturity of sector or many other useful perspectives. In this report however, it has been categorised into two broad classifications; positive (descriptive) case study reviews (i.e. those that have had a stronger focus on simply describing the occurrences of a renewable energy technologies diffusion within a location over a period of time), and those normative (prescriptive) case study examinations.

2.2.1 Positive (Descriptive) Research

Many historical studies of successful renewable innovation have been based upon the Danish wind industry which, having been a dominant manufacture of wind energy technologies since the mid-1970s, now exports over £4bn per annum accounting for 6.4% of Denmark's total exports (The Danish Wind Industry Association, 2012). Karnøe identified a great deal of bottom-up 'learning by using' that occurred in the 1970s as a result of socially motivating factors, (resistance against nuclear power and a desire for more environmentally benign power generation) (Karnøe, 1990, Rosenberg, 1982). Additionally, the establishment of several prominent supportive bodies such as the Organisation for Renewable Energy (OVE), The Association of Danish Wind Mill Manufacturers and the Test Station at Risø Research Centre, all helped to co-ordinate the large amount of informal, R&D activities [illegible]

Some academics have produced case studies focussed less on renewable energy technology but on other relevant efficiency improving energy technologies from which generalised lessons can be had. Watson for example discusses the success of the combined cycle gas turbine (CCGT) within the UK's energy system in the last decades of the 20th century (Watson, 2004).

2.2.2 Normative (Prescriptive) Research

There are a wider range of academics that have tried to identify thematic patterns and lessons from renewable energy case studies, some of whom are discussed further below.

Mallon outlines ten key features of successful renewable energy policy from a national level (Mallon, 2006). The first five of these are 'driver' specific in that they are policy elements that need applying to directly assist the renewables market; the second five are framework policies which are required to integrate renewables into the existing energy market/industry. These features can be applied with a more regional slant detailed below:

Driver Policies:

- Transparency: Policies are clearly visible and accessible to all potential stakeholders.
- Well Defined Objectives: Ensuring that the policy tools implemented fit with the wider policy objectives (or type three policy variable, see section 3.1) is crucial (Hall, 1993).
- Well Defined Resources and Technologies: Understanding the strengths and weaknesses of local factor conditions such as transport, labour and knowledge as well as the makeup of the regional renewable industry.
- Appropriately Applied Incentives: Ensuring that the correct policies are in place to meet these targeted outcomes without over-subsidising.
- Adequacy: Not only to the amount and duration of support provided but also the acknowledgement that initial support levels often required to 'kick-start' to overcome risk aversion from investors, incumbent inertia and bounded rationality of stakeholders (see section 2.1.3c)
- Stability: Highlighted as a critical factor in many renewable support issues. Ensuring that there are clear timelines and un-fluctuating policies minimises risks to investors, reducing the costs of capital and ultimately producing higher RE deployment for less overall cost.

Framework Policies:

- Contextual Frameworks: This refers to the overarching contexts in which policies are made. In regional assessments this will include a national (and international) understanding of the RE policy landscape but an understanding of the various framework models of innovation (section 2.1) as well as policy options is vial also.
- Energy Market Reform: The operational form of the energy market will always require a level of adjustment to integrate renewable energy technologies. Energy market reform policies are most likely to occur at national level however DNOs, suppliers, companies (and at times customers) within a region need to adapt to changes

- Land use Planning Reform: Reforming guidelines to incorporate the global benefits of RE generation is a strategic necessity to allow deployment and development to occur both onshore and offshore.
- Equalization of Community Risk and Cost-Benefit Distribution: The benefits of renewable energy are mainly enjoyed at a national level however the direct effects of an RE project tend to be at the local and community scale. Ensuring that there is equitability in the project for local stakeholders not only improves acceptance of the technology but is clearly an important aspect in ensuring planning acceptance. It is important also that this is not seen as simply 'paying off' the local community but rather, an equitable distribution of the benefits.

Haas *et al*. similarly identify several of these policy attributes, (such as long term stability of the support mechanisms) however they also argue for a stronger focus on project and capacity building aspects that must be in place such as sufficient prices for renewable electricity, easy access to the electricity grid and clear building codes (Haas *et al*., 2004).

Jacobsson has used early, (and un-refined) models of Technology Innovation Systems (TISs), (see section 2.1.2g) to identify challenges to policy makers that emerging renewable energy innovation presents (Jacobsson and Bergek, 2004). He identifies two key sector development stages, forming and expanding. Within the forming phase of a sectors development, he argues that the two primary challenges for policy makers are to at first, understand the functioning and complexity of the system, (itself an often overlooked or over assumed stage of analysis) and secondly, influence whole functional patterns of behaviour through coordination of ministries and agencies relevant to the sector and its incumbent. Once the system develops to an emerging and expansive stage, policy makers are then left to (sequentially) overcome four further challenges: Firstly, the alignment of different institutional goals to ensure a coherent policy direction and secondly to induce (non-directed) experimentation among different entrepreneurial actors. The third (and arguably most challenging stage) is to try and set in motion a process of *cumulative causation* whereby there is a self-re-enforcing dynamism within the innovative element of the sector. This final point can, and should be done with *powerful*, (in that they are effective at inducing change) *persistent*, (in that they have longevity enough to overcome both system inertia from incumbents and produce outcomes in the long term) and *predictable* (in that they can be both easily understood and are of manageable risk to stakeholders) policy measures. Additionally, there should be different supporting price signals for different generation types, (i.e. not one blanket subsidy for all renewables (Jacobsson and Bergek, 2004).

Connor compares wind industry development in several European countries with differing specific national motivations for their political agendas (Connor, 2003). He argues that (as with Karnøe's work) the type of governance has a strong influence upon both the available policy options within a country and also its historic level of success at prompting industrial development of wind technology. Specifically, more liberal economics have a laissez-faire approach to markets and therefore have either higher barriers to market intervention or are simply less willing to intervene in their operation. This has historically produced both a lower rate of deployment and a lower industrial base. Additionally, liberal markets have been less inclined to use soft forms of protectionism (such as preferential grant or loan subsidies) then more coordinated national economies. Echoing Porter's work, Connor argues that without a healthy domestic demand, international competitiveness is severely restricted (Connor, 2003).

There have been several works focussing specifically on the emergence of the UKs marine energy sector as a technology which (due to the obviously relevant nature to this report) are therefore discussed in greater detail below:

Jeffrey conducted direct interviews to draw out tacit understandings of problems and barriers within the sector and convert this into codified, explicit information (Jeffrey, 2007). He identified a *lack of physical validation* on resource modelling, electrical grid and economic appraisal was present. He also identified a *lack of knowledge* regarding both environmental effects as well as a lack of overall understanding of the marine resource was present. Broadly, he found that offshore (rather than nearshore) was the most favourable future technology, that there was disparity within the industry between complex, (higher output) devises and simplified (survivable) ones. Finally, he found that *maintenance requirements were a concern* for many (Jeffrey, 2007). Winskel translates work undertaken through a UKERC Sustainable Technology Programme into a marine energy innovation system study (Winskel *et al.*, 2006). Drawing on other sectors' historical emergence, (such as the wind industry) he identifies differentiating elements of the UK marine energy sector such as *Scotland's prominence* as a devolved country, *limited linkages between a few leading* developers, component suppliers and universities, and a general need for higher innovative network integration within the sector. Other, less formal aspects such as a lack of; 'failure tolerance' and design diversity were also identified. Winskel also reflects on some of the innovation systems literature highlighting the (false) pretence that 'interactive learning' is simply an 'everybody wins' scenario which clearly ignores conflicts of self-interest such as closely guarded IP and competitiveness which are strong drivers within the marine energy sector (Winskel *et al.*, 2006). This is also discussed further by Vantoch-Wood *et al.* (Vantoch-Wood *et al.*, 2012, Vantoch-Wood, 2012b).

Dalton, has written on non-technical barriers to wave energy development specifically within Ireland (Dalton *et al.*, 2009). He classifies barriers as regulatory, logistical and financial. Much of his work is positive (in that it suggest simply what is occurring rather than giving normative policy suggestions) however he identifies that test centres should provide; EIA waivers, free cable connection, free data collection and adjacent service facilities. For regulatory policy; specific targets should direct policy; certainty in remuneration and revenue for projects grants and support as well as tax concessions, simplified planning and licensing and a supportive grid connectivity network should all be in place to ensure deployment (Dalton *et al.*, 2009). In further work Dalton specifically assesses Ireland in terms of innovation, manufacturing and deployment (with comparison to other nations RE policies). He concludes that Ireland has fostered a positive deployment strategy historically (although not so successful on manufacturing) however there are several key areas that should be improved upon including: *the creation of a wind energy strategy group* (to provide developer-user learning), *an increase to R&D budgets*, the *development of developer specific grid codes and standards*, the *establishment of a 30% capital grant subsidy* system and a *3-5% corporate tax reduction system for developers*, a *planning 'fast-track' mechanism*, an *increase of feed in tariff* and (for overall legitimacy and confidence in policy) *a stable government* (Dalton and Ó Gallachóir, 2010).

Finally, specific to the south west UK, which is the focus of this report, there have been several publication (related to the Wave Hub site) that have focussed upon stakeholder perceptions and site development. Connor discusses the various conflicts and challenges with different environmental impact measurements as well as the obvious problems that these discrepancies can cause with local stakeholder groups (specifically the effect of deployment upon the surfing community in North Cornwall) (Connor, 2007). Stakeholder views are investigated further by West who identifies consultation failures and successes within the Wave Hub experience, specifically failures at informing 'grass root' stakeholders. She also suggests that a pragmatic and cautious approach should be adopted when highlighting the potential benefits of the scheme as overly inflated expectations have the potential for strong stakeholder disillusionment and hostility (West *et al.*, 2009).

2.3 Metrics of Innovative Behaviour

2.3.1 Introduction

There are a wide and extensive range of metrics that are used within studies of innovation to provide proxy indicators for a wealth of functionalities and insights. These range from bibliometrics, employment/graduate figures and straightforward gross R&D support levels to more obscure measures such as the evidence of intermediate goods, network analysis and process analysis (Hekkert *et al.*, 2007, Vantoch-Wood, 2012a). Many of these measures are used to provide inputs into different systems of innovation analysis. Additionally many institutes and companies have developed sectoral, regional or national specific measures of innovation to gain an insight into the overall innovative capability of a given system. Some of the most prominent works on methodologies for acquiring innovation metrics published by the OECD (OECD, 2002, OECD, 2005). Below however, is an overview of a few key measures that can be used to assess the more direct innovative output of either a sector (through aggregated assessment of key actors) or a single entrepreneurial stakeholder in terms of specific progress within a given technology system.

2.3.2 Patents

Despite their known limitations, patents are one of the key indicators for innovative activity and are especially important in high technology research led industries. Inventors take on the risks associated with research and development, (R&D) under the premise that once a successful invention occurs, there work will be rewarded. The reward for this often comes in the form of a patent. Dosi outlines the following characteristics of specific patents, (Dosi et al., 2006) as follows:

- Patent Life: Simply defines the length of time a patent is applicable for.
- Amplitude, (breadth or diversity): This relates to the technological breadth of the patent in that it dictates the minimum number of components that must differ.
- Amplitude, (depth or improvement): This can be thought of as the minimum level of

Historically, patents have allowed the inventor the right to prevent others from imitation: i.e. the right to excludability. Those that created the patent would have to be the one that fully commercialised the invention, (i.e. turn it into a successful innovation) or simply stop others from commercialising it themselves. In more recent decades however, the strengthening of patent laws and refinement of modern business practices have meant that the value of patents has taken a much wider understanding and the following strategic applications of patents can be applied:

- Offensive strategy: Used to protect a monopoly over use on an invention (exclusion).
- Market strategy: Used to trade technologies with other sectors and potential users.
- Defensive strategy: Specifically within high complexity goods. Patenting allows for cross-licensing and thus prevents exclusion of use. (This is in effect attempting to mend the 'tragedy of the anti-commons' described below.)
- Reputation strategy: Patents are used to certify and signal competences to other companies and potential investors.
- Partnership strategy: Forcing companies to collaborate over projects through a form of patent bargaining.
- Open strategy: From a wider social good, to diffuse or free technologies from ownership, (like for example the freeing of hypertext mark-up language, (HTML) by CERN which allowed for the mass explosion of the internet.)
  (Julien, 2009)

This diversification in patent use has led to a much greater role for intellectual property rights (IPR) management. Patents themselves are now seen as more of a product or tool before any successful commercialisation of the patent occurs. Concepts such as patent pools and patent markets are more common and not only have the number of patents being applied for and approved, shot up in the last few decades, but the individual value of each patent has dropped in what has become known as the 'patent paradox' (Julien, 2009, Kortum and Lerner, 1999). This paradox has, (in high technology sectors) been seen to lead to patent 'thickets' or the 'tragedy of the anti-commons.' The premise is somewhat different from its better known counterpart, the tragedy of the commons, whereby the availability of a common good leads to it's over utilization and deterioration since there is no ownership safeguarding it and it is in no one's specific interest to stop utilizing it if they are the only one to do so. In the tragedy of the anti-commons, overly diffuse ownership of a resource (or in this case overly patented technologies) results in sub-optimal utilisation of the resource since access rights are severely limited by the potential risk of litigation. At worst, this leaves researchers unable to access the inputs for their own innovation and at best requires time consuming negotiations. (Chesbrough et al., 2006) Even once patent licences can be resolved, multiple marginalisation of costs forces the overall product to be far more expensive. From a policy perspective, this is an innovation inhibitor and should generally be avoided as it stifles industrial development. One methodology thought to assist with this dilemma is the use of patent pools (discussed further in section 3.3.3d).

2.3.3 Technology and Manufacturing Readiness Levels

An important metric within policies focussed at technology and innovation promotion, is that defining the maturity of the actual technology under examination, (as opposed to the market development phase discussed within section 2.1). Almost all technologies (with the exception of radical breakthrough innovations) naturally begin as un-commercial concepts, usually within an R&D led, design office or even an entrepreneurial inventor's workshop. As a technology matures, it passes through various recognised stages; computer modelled, sub component testing, scale modelling etc. before (if all goes well) finally being rolled into a 'production line' technology. Although this may not mean that the technology is 'market competitive,' once a technology has been both built and diffused at full scale, future improvements and adjustments to the overall design of the device will tend to be incremental in nature. Likewise, future cost reductions will be as a result of both incremental improvements within the design and build of the product as well as cost reductions from supply chain cost reduction and production scale efficiencies (see learning and experience curves, as discussed in section 2.3.5 below).

To measure the progression of technology maturity for a specific innovative company, policy makers have started to adopt the Technology Readiness Levels (TRL) scale as a shorthand evaluation measure for emerging low carbon innovations, (with the acknowledgement that supplementary expert judgement is required to evaluate the performance of any technology at its current TRL). The TRL scale was initially conceived by NASA as a method for flight readiness assessment within its wider space programme but has since been adopted by other large technology design and procurement bodies including the US Department of Defence and more recently, the US Department of Energy (Assistant Secretary of Defense for Research and Engineering (ASD(R&E)), 2011, Mankin, 1995, DOE, 2011). Table 1 below outlines the TRL scale in application to renewable energy technologies assessment.

TRL	Definition	Description
1	Basic principles observed and reported	This is the lowest level of technology readiness. Scientific research begins to be translated into applied R&D. Examples might include paper studies of a technology's basic properties or experimental work that consists mainly of observations of the physical world.
2	Technology concept and/or application formulated	Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are still limited to analytic studies.
3	Analytical and experimental critical function and/or	Active research and development (R&D) is initiated. This includes analytical studies and laboratory-scale studies to physically validate the analytical predictions of separate

	characteristic proof of concept	elements of the technology. Examples include components that are not yet integrated or representative tested with simulants.
4	Component and/or system validation in laboratory environment	The basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of ad hoc hardware in a laboratory and testing with a range of simulants and small scale tests.
5	Laboratory scale, similar system validation in relevant environment	The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. Examples include testing a high-fidelity, laboratory scale system in a simulated environment with a range of simulants.
6	Engineering/pilot-scale, similar (prototypical) system validation in relevant environment	Engineering-scale models or prototypes are tested in a relevant environment. This represents a major step up in a technology's demonstrated readiness. Examples include testing an engineering scale prototypical system with a range of simulants.
7	Full-scale, similar (prototypical) system demonstrated in relevant environment	This represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant environment. Examples include testing full-scale prototype in the field with a range of simulants in cold commissioning[2].
8	Actual system completed and qualified through test and demonstration.	The technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental testing and evaluation of the system in hot commissioning.
9	Actual system operated over the full range of expected mission conditions.	The technology is in its final form and operated under the full range of operating mission conditions. Examples include using the actual system in hot operations

Table 1: The Technology Readiness Level (TRL) Scale. Adapted from: (DOE, 2011)

Along similar lines, the US Department of Defence (DOD) have also developed a Manufacturing Readiness Level (MRL) scale which, in conjunction with the TRL, allows for the quantification and codification of a company/institute's ability to (re-)produce technologies in an larger scale production process, (rather than a singular bespoke system. Although the MRL scale is less widely applied than TRLs, it has important application for supply chain and deployment scaling efficiencies of 'incrementally' produced renewable energy technologies such as wave, tidal and floating wind technologies (i.e. where incremental deployment of multiple devices are expected to be occur rather than the 'binary' deployment of large and centralised generation technologies such as nuclear or combustion plants).

This is because the process by which incrementally manufactured and deployed renewable energy technologies can be improved upon (and eventually mass produced) is subject to much greater cost reducing opportunities throughout the 'tooling up' process for mass-production, (i.e. bespoke manufacturing costs of first-of-a-kind (FOAK) units are significantly higher than the final assembly line product cost, referred to as the Nth of a kind (NOAK)).

The MRL scale is comprised of several more dimensions than the TRL however as an overview, is illustrated in Table 2 below:

TRL	Definition	Description
1	Basic Manufacturing Implications Identified	The focus is to address manufacturing shortfalls and opportunities needed to achieve program objectives. Basic research (i.e., funded by budget activity) begins in the form of studies.
2	Manufacturing Concepts Identified	Characterized by describing the application of new manufacturing concepts. Typically this level of readiness includes identification, paper studies and analysis of material and process approaches.
3	Manufacturing Proof of Concept Developed	Validation of the manufacturing concepts through analytical or laboratory experiments. Typical of technologies in Applied Research and Advanced Development stage. Materials and/or processes characterized for manufacturability and availability but further evaluation and demonstration is required.
4	Capability to produce the technology in a laboratory environment	Required investments, such as manufacturing technology development, identified. Processes to ensure manufacturability, producibility, and quality are in place and are sufficient to produce technology demonstrators. Technologies matured to TRL 4+.
5	Capability to produce prototype components in a production	Industrial base has been assessed to identify potential manufacturing sources. Manufacturing strategy refined and integrated with risk management plan. Identification of enabling/critical technologies and components is complete. cost model constructed to assess projected manufacturing

		cost. Technologies matured to TRL 5+.
6	Capability to produce a prototype system or subsystem in a production relevant environment	Initial manufacturing approach developed. Prototype manufacturing processes technologies, materials, tooling and test equipment, as well as personnel skills have been demonstrated in relevant environment. Long-lead and key supply chain elements have been identified. Technologies matured to TRL 6+.
7	Capability to produce systems, subsystems, or components in a	System detailed design activity is nearing completion. Material specifications approved . Manufacturing processes and procedures demonstrated. Supply chain and quality assurance assessed and long-lead procurement plans in place. Production tooling and test equipment design initiated. Technologies on a path to TRL 7.
8	Pilot line capability demonstrated; Ready to begin Low Rate Initial Production	Detailed system design complete and sufficiently stable to enter low rate production. Materials, manpower, tooling, test equipment and facilities are proven and available to meet planned low rate production schedule. Known producibility risks pose no significant challenges for low rate production. Technologies matured to TRL 7+.
9	Low rate production demonstrated; Capability in place to begin Full Rate Production	Full Rate Production (FRP). All engineering/design requirements met. Materials, parts, manpower, tooling, test equipment and facilities available to meet planned production schedules. Manufacturing process capability in a low rate production environment meet design characteristic tolerances. Technologies matured to TRL 9+.
10	Full Rate Production demonstrated and lean production practices in place	System, components or items are in full rate production and meet all engineering, performance, quality and reliability requirements. Rate production unit costs meet goals, funding is sufficient for production at required rates. Lean practices established and process improvements on-going. Technologies matured to TRL 9.

Table 2: The Manufacturing Readiness Level (MRL) Scale. Adapted from: (OSD Manufacturing Technology Program, 2010)

2.3.4 Measures of Deployment Efficacy

More developed technologies will have seen deployment occur, potentially s a result of efficacious policy will see (among other indicators) an increase in deployment rate. Several indicators of policy success for this stage are highlighted by the IEA as shown below (IEA, 2008):

Indicator	Formula	Advantages	Disadvantages
Average annual growth rate	$g_n^i = \left(\frac{G_n^i}{G_{n-t}^i}\right)^{\frac{1}{t}} - 1$	Based upon empirical evidence	No consideration of country specific background
Absolute annual growth	$a_n^i = \frac{G_n^i - G_{n-1}^i}{n}$	Based upon empirical evidence	No consideration of country specific background
Effectiveness indicator	$E_n^i = \frac{G_n^i - G_{n-1}^i}{ADDPOT_n^i} = \frac{G_n^i - G_{n-1}^i}{POT_{2020}^i - G_{n-1}^i}$	Consideration of country specific background	Difficulties in the identification of additional mid-term potential

Where:
g_n^i: Average annual growth rate.
a_n^i: Absolute annual growth rate.
E_n^i: Effectiveness indicator for renewable energy technology *i* in year *n*
G_n^i: Electricity Generation by renewable energy technology *i* in year *n*
$ADDPOT_n^i$: Additional generation potential of renewable energy technology *i* in year *n* until 2020
POT_{2020}^i: Total generation potential of renewable energy technology *i* until year 2020

2.3.5 Learning & Experience Curves

Learning and experience curves are ways of analysing the level of reductions in production cost that one would expect with and increased level of production (given the various factors that contribute to an economics of scales such as learning by doing etc)(IEA, 2000). A learning curve simply measures the decrease in cost (or increase in performance) in relation to one particular input (for example labour). An experience curve on the other hand, measures the performance relative to all the external inputs to the process (i.e. reductions in marketing, volume purchasing, improved manufacturing techniques etc.) and is often used within policy documents when assessing the expected overall cost reduction of increased deployment within renewable energy technologies (Wene, 2008). The generalised formula for the calculation of an experience curve is that a doubling of production produces a consistent percentage level of cost reduction, (for example between 10%-15%) as is shown in Equation 1 below.

Equation 1: General Formula for an experience curve (IEA, 2000).

Where:
P= the cumulative average cost or time per unit
A_0= cost or time required to produce the first unit
X= the cumulative number of units produced
E= the slope function when plotted on log/log paper, or the log of the learning rate, (e.g. 0.8 for an 80% cost at doubling of production) divided by the log of 2 (log(lr)/log(2)).

Graphically, this is exemplified in Figure 12 below which shows both individual and cumulative costs of production for a widget with a base cost of 100 and a learning rate of 0.85, (i.e. a 15% reduction of cost per doubling of production).

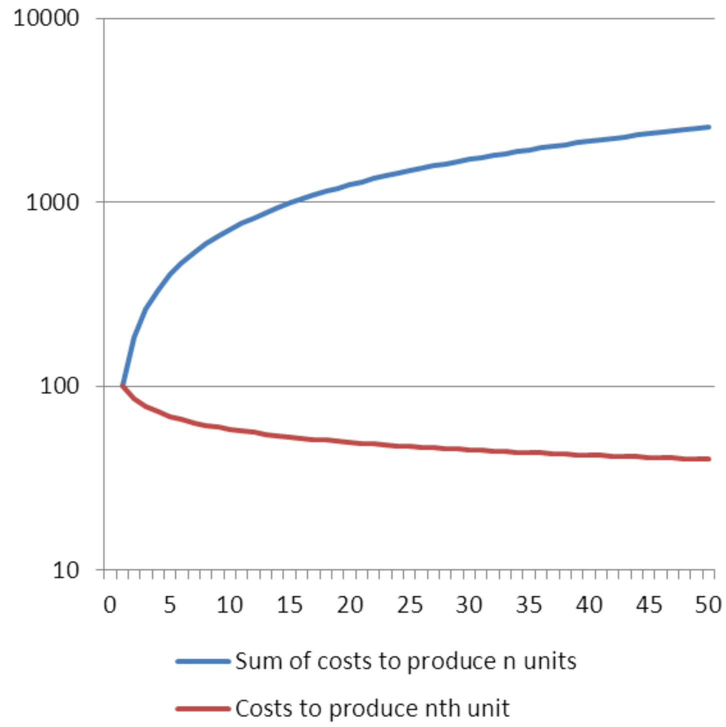


Figure 12: Example experience curves

A famous example of an experience curve is 'Moore's Law' which states that there will be a doubling (or a doubling of economic density) of the amount of transistors that can be placed inside an integrated circuit board every two years.

3. Key Support Options

The main body of industrial support options that are available to renewable energy policy makers has been broken into two broad conceptual categories: financial and non-financial policy support options. An oversight of these options is provided below, the list is clearly not exhaustive and as each sector is unique, bespoke solutions may be the best choice available. Foxon *et al* (2005) make it clear that different policy options may suit technologies at different stages of technological development. Experience with applying policy also suggests that since technologies are subject to multiple barriers to deployment that mixtures of financial and non-financial instruments will be needed to overcome these concurrently. Conversely, the system of governance under which policy is to be introduced may preclude some support options. This is specifically the case with financial support options where anti-protectionist laws (such as EU state aid restrictions) will prevent policy makers from providing what is considered to be excessive subsidised support.

3.1 Introduction to Key Support Option

Specifically focussing on the UK, Hall identifies three separate variables of policy (Hall, 1993). These are labelled as type one to three: Type one relates to the level at which the particular policy instrument is set, (e.g. the amount of deployment subsidy that is in place etc.). Type two variables relate to the policy tool/instrument itself that is being used, (e.g. subsidising deployment; creating forums for overcoming industry wide problems etc.). Finally, type three policy relates to the overarching policy objective being undertaken, (e.g. increase deployment of marine renewables; create industry within a region etc.). Although the adjustment of these first two variables are somewhat standard in the course of a wider policy objectives' evolution; type three changes represent a radical paradigm shift within the policy landscape in that they re-set the motivation for the entire endeavour. From this taxonomy therefore, three forms of *learning* are identified ex-post. These are first order learning, (resulting in incremental changes to the policy instruments level), second order (relating to the type of instrument being deployed), and third order (which effectively kills the overall policy push since it implies a change in overall goal or direction). This process of learning will then inform the next stage of policy appraisal and implementation (Hall, 1993).

The UK Treasury Department provides a more elaborated framework for the appraisal, implementation and evaluation of policies options which gives a more incrementally refined chronological dimension. This guidance is presented in the conceptual model of the ROAMEF Cycle (HM Treasury, 2003). ROAMEF, (Rationale, Objectives, Appraisal, Monitoring, Evaluation and Feedback) is the appraisal loop by which policy makers ensure that there is efficacy of policies in central government. This cycle is shown in Figure 13 below.

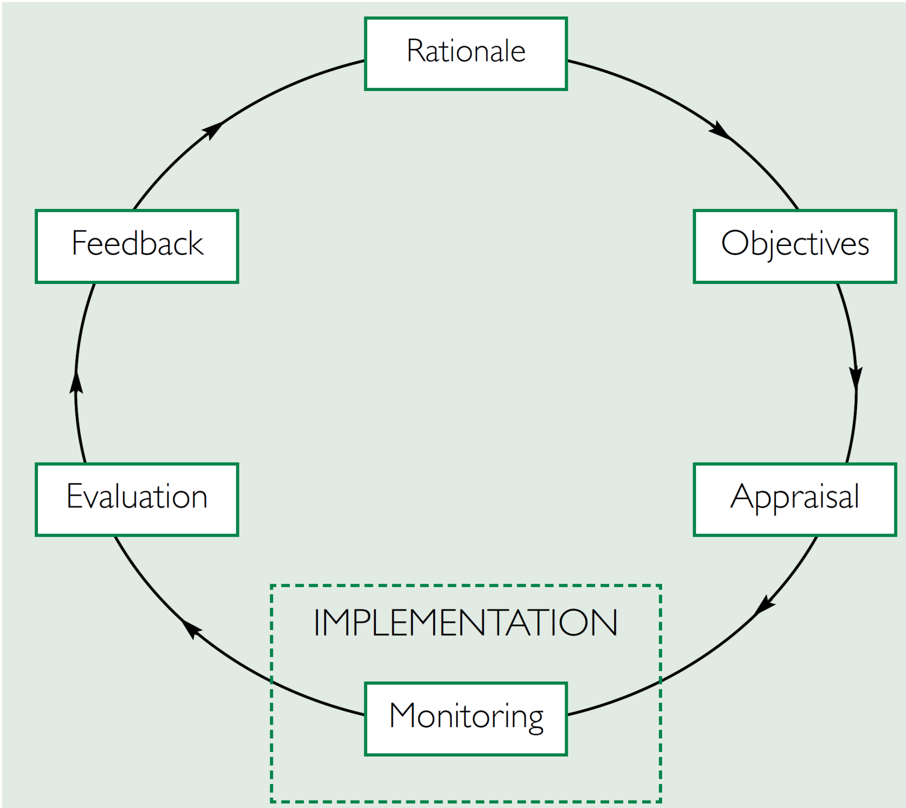


Figure 13: The ROAMEF Cycle

The conceptual application of this has relevance at both regional and localised levels as well as within non-fiscal policy making. The cycles of analysis are as follows:

- Rationale: Here, it is important to emphasise clarity of rational for why the policy is being made and ensure that it is reasonably assumed to be 'cost effective' in consideration to other alternatives.
- Objectives: This stage is where objectives, outcomes and targets are defined. Targets should be; specific, measureable, achievable36834(l)0159(f)-0.30m(t)-0.308417(s)-0.bll

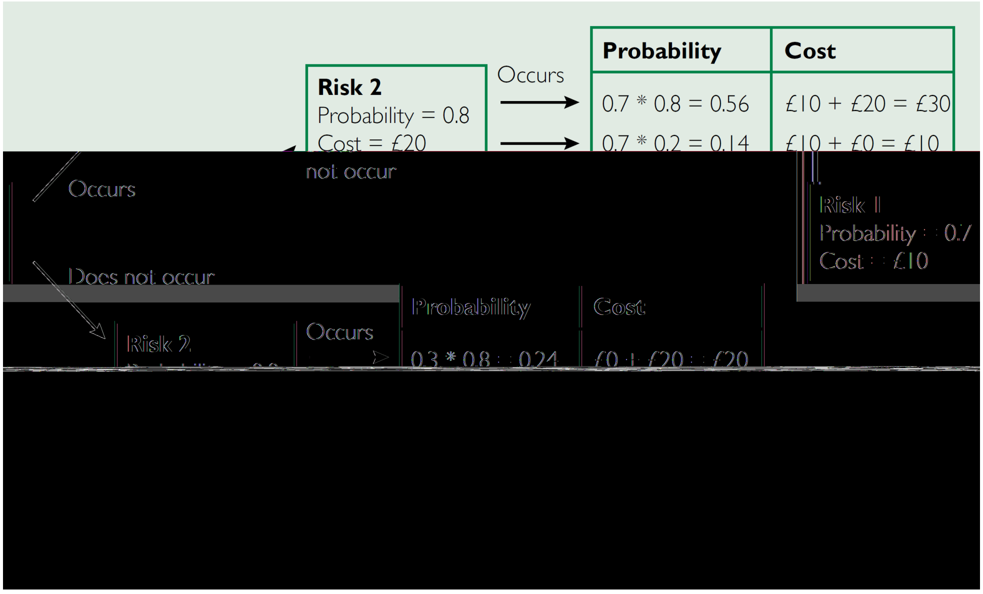


Figure 14: Decision making tree used to appraise fiscal policy options

- Monitoring/Implementation: Conducted concurrently, before the policy is rolled out, methods for measuring outcomes should be identified and (where necessary) ready to start.
- Evaluation: Evaluation is the Ex-post analysis and publication of the policy and its outcomes based upon the ex-ante, (appraisal).
- Feedback: The final stage of policy, feedback into the overall policy environment of the outcomes to inform if and how later stages of the same policy goal (type three policy) are to be addressed.

The two main sub-sections below outline the fiscal and non-fiscal policy options that are potentially available to policy makers, some of which would not be valid or applicable to the ROAMEF however many of which could be framed within this. There is also a strong element of bespoke appropriateness to all policies: Some of these are more or less applicable at different levels of governance, in more or less remote locations and clearly in different countries and with different overall political landscapes. Regional government remit is usually directed heavily by central governance agenda, (see section 2.1.1c) as well as limited in its supporting capacities both fiscally, (e.g. its in-ability to interfere with the electricity market) and non-fiscally (e.g. its inability to change national planning directions).In some aspects however, regional governance has a more advantageous position to central government in assisting with the commercialisation of a technology within its region (e.g. promoting regional businesses networks or developing regional planning strategies.

3.2 Direct Fiscal Policy Options

Direct financing of either companies or projects (t

Certification:	Certification Body:	Description:	Duration:
Basic Offshore Safety Induction & Emergency Training	Offshore Petroleum Industry Training Organization (OPITO)	Basic requirement for personnel intending to work on an offshore installation in the UK	3 Day
Personal Survival Techniques Certification	Standards of Training, Certification and Watchkeeping (STCW)	Basic requirement certification that is required for all contractors intending to work offshore. (Including boat works)	1 Day
Offshore Medical Certificate UK	United Kingdom Offshore Operators Association approved physician	Basic medical certification required for all offshore works (Including boat works)	NA
WTG Wind Turbine Climber Certification	British Wind Energy Agency	Basic course for working within wind turbines, (potentially transferable to wave/tidal devices)	2 Day
Rope Access training Certification (1<3)	Industrial Rope Access Trade Association	Differing levels of rope access certification required for all rope access works	5 Days +
Slinging and lifting Certification	Various	Certification Required for "Lifting Operations and Lifting Equipment Regulations 1998" (LOLER)	1 Day

Table 5: Indicative vocational skills training options for transferral of skilled labour to work within marine renewable energy

In addition to these skills, it is recognised that there will be a need for experience to be

Scope of works can be broken into the following sub-categories:

Services:	Examples:
Auxiliary Unskilled Services	Catering, taxis, security, general labour, cleaning, hygiene and waste management services.
Auxiliary Skilled Services	Accounting, legal and training services
Secondary Generic Services	Boat services, scuba dive services and some electrical, engineering and fabrication works, dredging services
Secondary Project Specific Services	Turbine servicing and monitoring, agency services.
Primary Generic Services	Large fabrication, offshore and onshore civil, engineering or electrical works, port facilities
Primary Project Specific Services	Jack-up barge services, turbine erection and commissioning, electrical design, project management
Components:	Examples:
Auxiliary Basic Components	Fuel, building materials, lubricants and consumables
Auxiliary Technical Components	Tools, ship chandlery, miscellaneous components
Secondary Generic Components	Small electrical and steelworks, marine paints
Secondary Project Specific Components	Transition pieces, barge modification works
Primary Generic Components	Foundation aggregate, sub-sea cables, transformers
Primary Project Specific Components	Turbines and foundations

B: Scale of works:

Here companies invested in capital resources (such as boats) or increased their staff to allow them to tender for larger contracts. Increasing scales of work can be applied to any of the above categories.

Although both of these processes of engagement hold differing limitations and opportunities (scale of works for example is limited by the fact that larger contracts are given out at an early stage in project construction), the below diagram shows a conceptual insight into the methods for localised contract engagement:

Figure 17: Conceptual overview of local company supply chain engagement

The above diagram shows Company A is diversified across a wider scope of operations, (this could be the result of increased training for example) whereas company B has specialised in the supply of a specific secondary generic component, (steel fabrications for example.) This diagram shows how both companies receive equal percentage of the total project value, (around 3%) by expanding into different project opportunities.

Looking at maximisation of local project spend, there are two approach strategies which policy makers can use increase localised spend. These are: Increasing the capabilities of local companies and; decrease market entry barriers for local companies. As with the above diagram, this can be broken into scale and scope operations as can be shown in the below matrix:

	Scale of Works:	Scope of Works:
Increasing Capabilities:	Increasing staff levels Increasing capital equipment	Increasing skills and training within existing operational base Increasing skills and training within project specific skills, (such as rope access, sea survival, first aid)
Decreasing Barriers:	Early engagement with local contractors Increasing awareness of both services and contracts Breaking down sub-contract into smaller sizes of work	Early engagement with local contractors Increasing awareness of both services and contracts Breaking down sub-contracts into narrower scopes of work

There are clearly good business reasons for larger project contractors not undertaking certain actions that may help local spend. Breaking down larger contracts puts onus on the main contractor to ensure the work is complete rather than the sub-contractor. This is a risk increasing activity and thus not attractive to contracting firms.

Increasing capability factors however is a preferable option since it increases both availability options to the main contractors and adds value for the sub-contracting company.

One further factor to consider when assessing the business opportunities from offshore renewable deployment is the time specific nature of deployment within most projects. As an offshore project is undertaken, activity around the main construction and deployment site increases to a maximum and then begin to decrease as installations and project elements are completed. A baseline minimum of O&M remains for the lifetime of the project. The finite time-specific nature of the construction phase does not however rule out long term economic benefits, skills improvement or market diversification within the region. Additionally, once skills, experience and trust has been acquired, local companies have the opportunity to either diversify into other supporting industries (e.g. other offshore works) or increase the geographic catchment of their works (e.g. national or international) to gain further work.

Future employment estimates for offshore RETs within the UK are shown in Figure 18 and Figure 19below . These show both the deployment and employment estimates are far higher for offshore wind technology than wave and tidal technology.

Figure 18: Medium deployment scenario, employment estimate within the UK offshore wind industry (RenewableUK, 2011)

Figure 19: Medium deployment scenario, employment estimate within the UK marine renewable (wet tech) industry (RenewableUK, 2011)

General Business/Admin/IT Support training

Many smaller specialist businesses have a strong core competency (e.g. electrical or welding services) however may be inexperienced within more generalised skills such as basic accounting, IT or business and management. This is something that has been highlighted as a priority requirement within the South West, where smaller regional businesses have been found to lack what could be reasonably expected within these business skill sets (South West Science and Industry Council, 2008). This could be provided through specialist support bodies whose mandate is to promote business skills (such as Cornwall Marine Network within Cornwall) or through the operation and management of business incubators, which may provide additional services as part of their remit.

3.3.3d Other

Open Innovation Models

Patent management mechanisms are less prevalent within liberal market economies (see section 2.1.1a) however the concept of open innovation supports instruments such as patent pools, strategies, technology spin-in/spin-out and license-in/license-out (Chesbrough *et al*., 2006). Open innovation is an alternative model of looking at the process of innovation that varies from the established 'closed' model in that it attempts to decouple the R&D innovation process from the corporate value chain (i.e. from the sales/marketing strategy) and widens the scope of R&D inclusion to include users, supply chain companies, relavent stakeholder groups and even in cases, competitive companies to both maximise the value of an innovation as well as identify new roads to commercialisation. Open innovation seeks to mitigate innovation inhibiting factors such as 'not-invented here', 'bounded rationality' and to some extent 'technology lock in' (see section 2.1.3c) through a widening of the R&D search heuristic. This can be done through conceptual tools such as 'living labs' in which users are intrigue to both the value adding and innovative behaviour of R&D (e.g. linux software, Wikipedia).

These non-standard mechanisms for innovation stimulation have scope for practical exploration within both the offshore renewable energy sector and renewable technologies overall however appropriate 'buy-in' from industry is required for concepts of open innovation to work. The advantage of many of these systems is that they provide methods for both diversification for larger established companies (who already have patents/licenced products) as well as revenue generation (for smaller IP based innovative companies) with lower investment risks (Chesbrough *et al*., 2006). Many of the policies used to support regional open innovation include existing network and cluster promoting instruments, (see section 2.1.2e for innovation cluster theory and section 3.3.3a for networking theory) however there are more open innovation specific policies that can be applied within a geographic region. Public sector run patent pools for example are something that has the potential to specifically allow multiple established, start-up and university, (or joint academic/industry) spin-off companies to promote their concepts without duplication of effort. Within these pools, the cost of the overall product can be kept lower as the patents themselves are relatively 'worthless' to the particular product market without the patent owner's involvement. If pooled, the patents are centrally administered and licence for all potential applications as they arise. The pool therefore becomes a royalty generating 'tool box' of patented inventions accessible to all those participating in the pool. (Chesbrough et al., 2006). A similar mechanism for assisting commercialisation is currently being run in Scotland through Scottish Enterprise's Proof of Concept Programme (PoCP). This programme however has a narrower focus, working specifically with Scottish universities only (although across a wider range of technologies) but also with a focus on directly supporting pre-prototype inventions reaching proof of concept stage (Scottish Enterprise, 2012). Within the UK a similar approach could perhaps be managed by UK Trade and Investment (UKTI). It circumnavigates state-aid laws by focussing on universities directly and thus can provide 100% finance (following an assessment process).

3.3.4 Specific Infrastructure Support

In addition to the above supporting measures, there are a host of required infrastructural factor conditions, both specific to the promotion of offshore renewable energy technologies (in some cases being more relevant to specific technologies even) and more generally that can help to facilitate innovation within the region. Infrastructural improvements tend to be higher cost measures but can make an importance difference to the future cost of projects and can also be more effectively targeted (at port facilities for example) to increase policy efficacy. These are discussed individually below.

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